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QUALITY CATEGORIZATION OF AERIAL RECONNAISSANCE PHOTOGRAPHY

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ROME AIR DEVELOPMENT CENTER
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AIR FORCE SYSTEMS COMMAND
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FINAL REPORT

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CAL Report No. VE-1667-G-1
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CORNELL AERONAUTICAL LABORATORY, INC.
OF CORNELL UNIVERSITY, BUFFALO 21, N. Y.

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FOREWORD

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ABSTRACT

The derivation of a summary measure which would relate measurable photographic parameters to the information content which a photointerpreter could extract from the photograph was investigated. Four parameters of quality were chosen which describe image contrast, grain, and modulation curve (resolution and passband). Image modification methods and measuring techniques which could be used without recourse to test charts were developed for black and white photographs. A thousand photographs with a range of quality parameters were generated and used in interpretation tests. Standard statistical methods were employed in an attempt to obtain the correlation between the photointerpreter scores and the measured variables of the photographs. However, these procedures did not permit a meaningful summary measure to be derived, primarily because of the low scores achieved by the photointerpreters who took the test. Conclusions have been drawn relating to image modification, measurement of quality parameters and planning of future tests.

PUBLICATION REVIEW

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This report has been reviewed and is approved.

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SUMMARY

The derivation of a summary measure which would relate measurable photographic parameters to the information which a photointerpreter could extract from the photograph was investigated.

The four parameters chosen to describe photographs were: (1) grain, a measurement of the root-mean-square density fluctuation observed in a microdensitometer scan across a uniformly exposed area of a film, (2) contrast, defined as the average of the six largest monotonic density changes observed in a scan across the photograph, (3) passband, the area under the square of the modulation transfer function, and (4) resolution, the spatial frequency at which the transfer function equals 0.25.

Two interpretation tests were conducted during this program. The first was a pretest, involving 200 photographs, designed to improve the modification procedure and interpreter testing methods. The second test involved the modification and measurement of quality parameters of 1000 photographs of which 760 were used in the test. This test was designed to determine the summary measure.

The thousand photographs were generated by modifying the four parameters in the following manner: (1) grain was controlled by using different types of film, (2) contrast was controlled by veiling exposures, and (3) passband and resolution were controlled by spatial filtering.

Apparent discrepancies between the level of performance required on the determination test and the existing level of subject capability created low average scores which made it impossible to derive a summary measure.

The results of the study include the development of image modification procedures and the generation of a set of modified photographs, the extension of measurement techniques to provide quality measurements for aerial photographs without recourse to test charts, and information regarding the design of photointerpretation test procedures.

I. INTRODUCTION

The study and the experimental program discussed herein were conducted at the Cornell Aeronautical Laboratory, Inc. under contract number AF 30(602)-2684 from the Rome Air Development Center. The program was directed toward the derivation of a summary measure of image quality for photointerpretation.

It is possible to formulate equations which relate the photographic image produced by a reconnaissance system to the original object scene. These equations contain parameters describing the effects of atmosphere, lens, film and image motion on the image. Although the values of several of these parameters still require investigation, and are in fact being investigated on other programs, the equations can be written in general form. However, at the start of this contract, the final photographic image quality could not be related by an equation to the potential performance of a photointerpreter in extracting information from the image. This missing link is the subject of the current effort.

If such an equation could be derived, that is a measure of interpretability expressed as a function of the physical image characteristics, several uses are apparent. The summary measure of image quality would provide a rating scale with which priorities could be established at times when the image acquisition process overloads the interpretation process. Further, by examination of the components of the quality measure, it would be possible to predict those cases in which enhancement is possible and foretell the form of enhancement which would be of the greatest value in increasing the quality. Using this approach, it can be seen that the summary measure also provides a design criterion for the synthesis of new reconnaissance systems. Lacking the summary measure, system optimization has been limited to an intuitive process.

The basic philosophy of this program was realism, i.e., aerial scenes were used, interpretation tests were performed by trained photointerpreters and the interpretation tasks were equivalent to those normally performed by experienced photointerpreters. In order to constrain the program to reasonable test size, and keep within financial limits, several limitations were imposed. Only monocular viewing of black and white photographs was included in this program. Since both color and stereo would add considerably to the complexity of the physical description, the physical parameters used are not a complete description of the image, but rather are a simplified description which is both comparatively easy to handle and precise enough to treat the more important situations. Finally, the ranges of variables are essentially limited to those which occur in present-day aerial photography.

The general approach to the problem is shown in Figure 1. Aerial photographs were selected according to a set of requirements on target content (number, types, size, etc.) and scale. This imagery was modified creating a set of photographs in which the physical quality varied. The needed parameters of each photograph were measured, and the photographs used in interpretative tests. The performance scores of the photointerpreters were correlated with the variables of quality to obtain a summary measure. This process is the subject of the following sections.

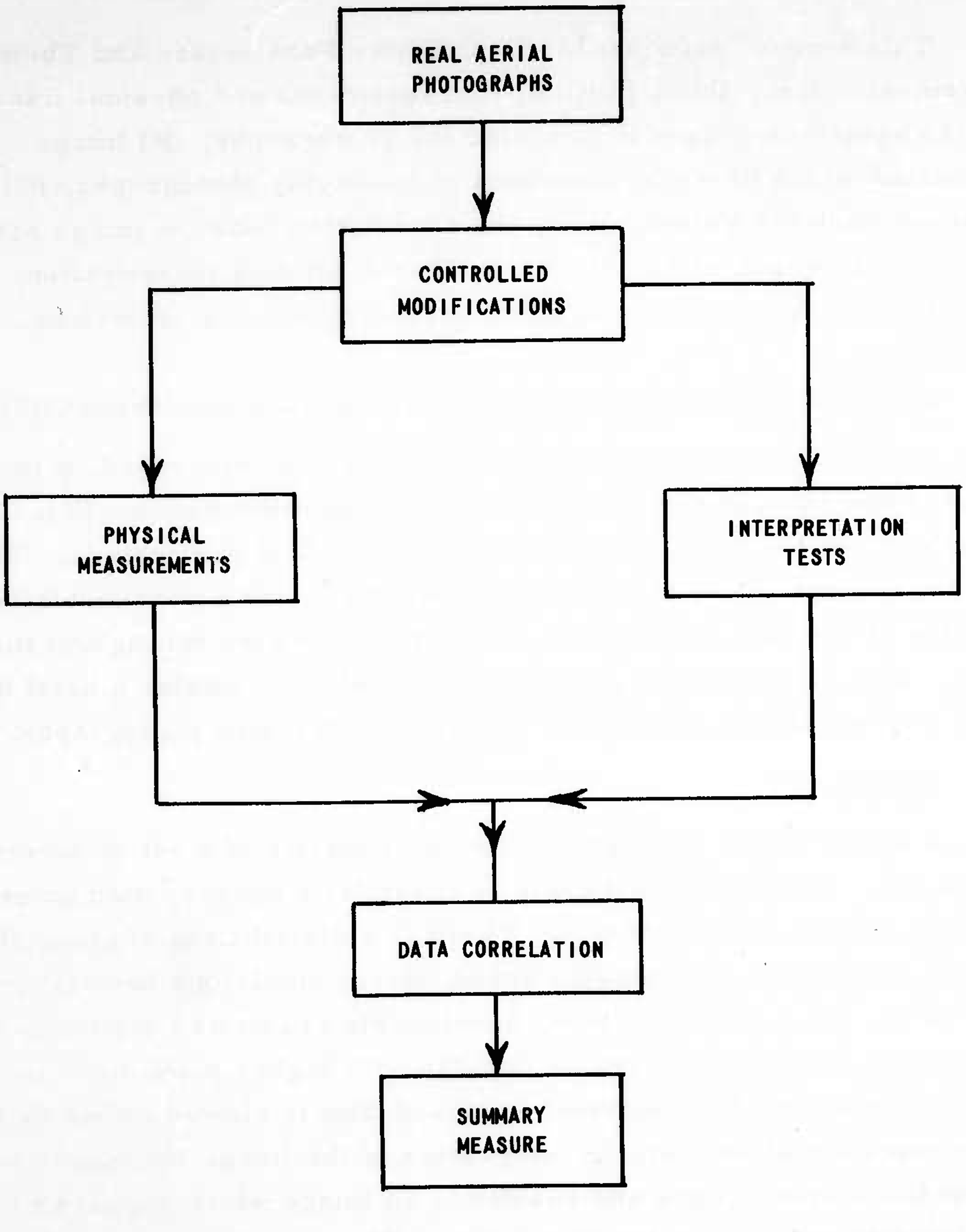

Fig. 1 APPROACH TO PROBLEM

II. GENERAL CONSIDERATIONS

This section includes: (A) Descriptive Parameters and Their Measurements, i.e., the definition, measurements and physical interpretation of the variables chosen to describe the photographs, (B) Image Modifications which describes methods of modifying photographs, (C) Selection of Variable Values, i.e., the correlation between image parameters and the ranges of variables considered for this investigation, and (D) Selection of Photographs and other psychological considerations.

A. DESCRIPTIVE PARAMETERS AND THEIR MEASUREMENTS

When physical photographic parameters are discussed, a long list of numbers and functions are used to describe photographic quality. Fortunately, the list can be reduced to a few independent parameters. The numbers discussed in the following sections represent a reasonably complete description of physical photographs, and are those used throughout this program. For completeness, however, Appendix I contains a brief description of other parameters which are used to describe photographs.

1. Granularity

A silver halide photographic image consists of a set of developed silver grains. Each developed grain is essentially opaque, with an essentially transparent gelatin surrounding it. There is a distribution of grain size with the average depending on emulsion speed (faster emulsions have larger grain sizes). In the unexposed emulsion, developable grains are randomly spaced. In the exposed image, these grains develop with higher probability in regions of greater exposure. If a uniformly exposed film is viewed either by the eye or with a microdensitometer, an integration of the image luminance over a small but finite area occurs and results in an image which appears to be a smooth function with a random fluctuation. The smoothly varying function is often called the signal while the random fluctuations are denoted as noise.

This noise in an aerial photograph is formed by the granular nature of the emulsion. The noise is a function of the emulsion used, the developing process, the average density level and the spatial frequencies over which it is measured. The first two factors are not involved in the measurement process and therefore need not be considered. The third factor can be taken into account most readily by making the granularity measurement at the average image density.* While the grain noise of copied or enhanced photographs can be a function of spatial frequency, original photographs have a nearly flat grain spectrum. Thus, the grain noise can be measured in the following manner. (This is similar to the method described in Eastman Kodak's Film Data Book.) If a photographic area receives a constant exposure, it can be safely assumed that the image "signal" is constant. When such an area is scanned with an aperture of area A, a root mean square density fluctuation σ can be determined. For a given film and developing process, these are related by

$$\sigma = G \cdot A^{-1/2} \tag{1}$$

where G is a constant called the Selwyn granularity constant.

In this program, the parameter of granularity is defined as the root mean-square density fluctuation of a uniformly exposed area of the scene. This corresponds to the number σ in the preceding equation.

The granularity is measured in any uniform area whose density (by visual inspection) approximates** the scene average (such as the roof top shown in 3 in Figure 2). The aperture used by Kodak (Film Data Book) is a 24μ diameter circle, but for convenience, a 10μ diameter circle was used in this study and when necessary for comparison correct by the relation:

$$\sigma_{24} \cdot 24 = \sigma \cdot D \tag{2}$$

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* It is important to note that granularity is a physical measure of an emulsion characteristic and should not be confused with the "graininess" which is the impression of grain when a photographic image is viewed.

** Since granularity varies slowly with density, the choice of density level is not critical.

MEASUREMENT TECHNIQUES

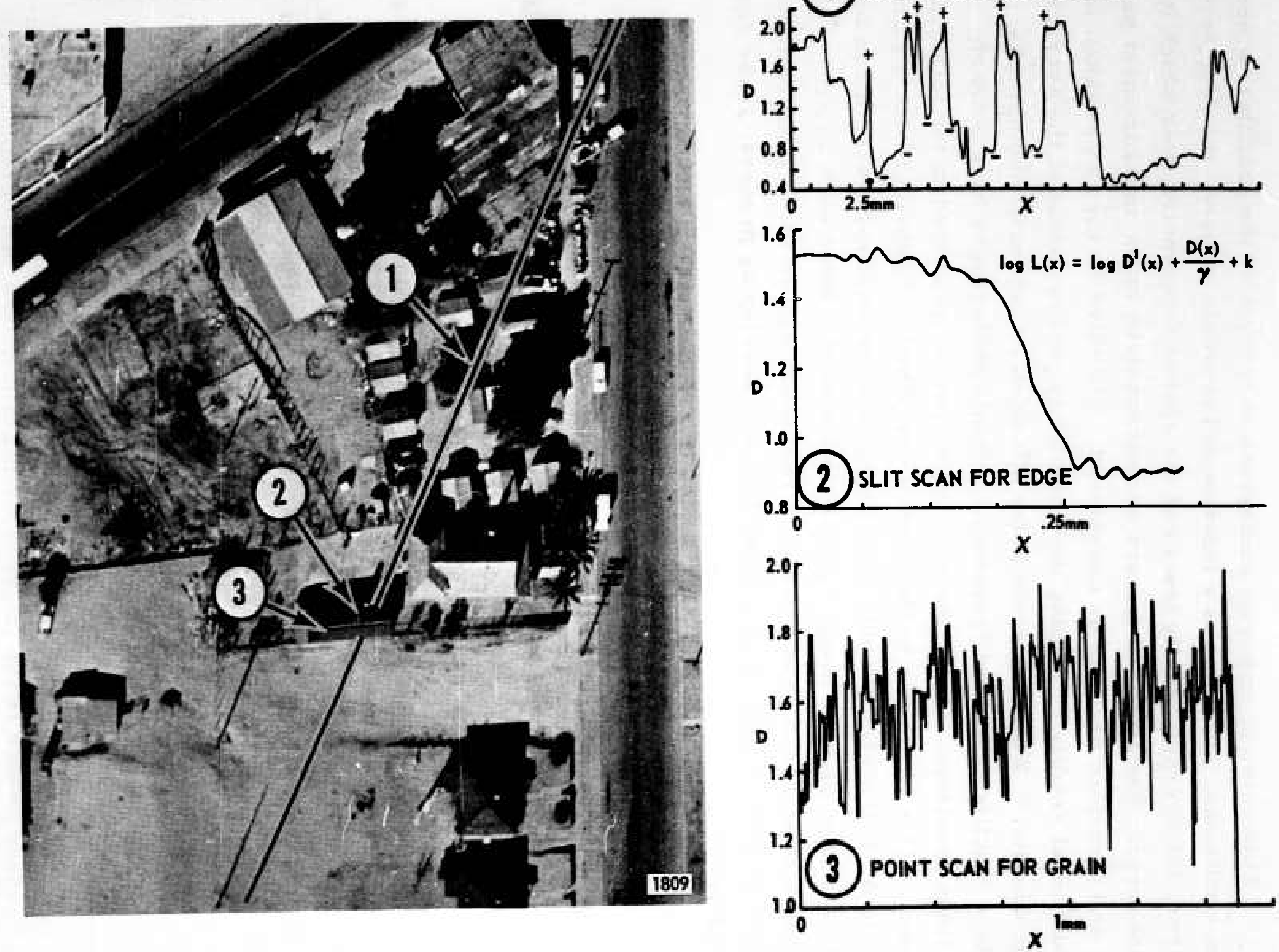

Fig. 2 MEASUREMENT TECHNIQUES

where σ is the granularity measured with a circular aperture of diameter D (in microns) and σ_{24} the granularity value corresponding to a circular aperture of 24μ. The area is scanned, providing a trace as shown in 3 of Figure 2, and the data were simultaneously sampled, converted to digital form and punched on paper tape for direct input to an IBM 704 computer. Approximately 1000 sample points were collected. A computer program did the following, (1) computed the average density and the root mean square density fluctuation (σ), of all the recorded points of a given scene, (2) separated density fluctuations from the average density into two groups; those greater than 2 σ and those less than 2 σ. This technique avoided the inclusion of transient and unusually large fluctuations of density due to scratches and dust spots. (3) Using only the points belonging to the "less than 2 σ " group, an average density and a σ were again calculated. This new value of σ was the parameter of granularity used in this program. All density points were punched at a rate providing approximately two samples per effective diameter of the aperture. No variations in σ were observed when the counting rate was reduced to one count per effective diameter. Measured values of σ fall in the range 0.02 to 0.16.

2. Contrast

In this program "contrast of a photographic scene" is defined as the average of the six largest monotonic density changes which occur in any microdensitometer trace of the photograph. The mechanics of the measuring process are: (1) a microdensitometer measurement was made of the density as a function of position on a portion of a representative line across the photograph. (2) From this density trace, the six largest monotonic density changes were determined and averaged. (3) This dimensionless number was designated as the contrast (See 1 on Figure 2).

All measurements of contrast were performed on a standard Ansco Model 4 microdensitometer equipped with a special stage capable of handling film up to a 9" x 9" format. A circular aperture of approximately 100μ effective diameter was used in the scans. This was large enough to integrate over small fluctuations due to grain but small enough to see the salient features of the scene. The trace was selected to cross some detail and the direction of scan was arbitrary. This precaution was used to prevent scanning only water in a seashore scene. Scans across the same photograph but in different directions yield contrast values which agree to within 15%.

In defining a scene contrast by this method, three cases can arise. The measured contrast of the selected targets and their immediate surroundings can be larger than, the same as or less than, the contrast of the general background. In the first two cases, the density difference of the targets and their surroundings should yield a contrast value which is the same as the scene contrast and be a logical extension of the usual definition of contrast of a single object surrounded by a uniform background. In the third case, the scene contrast will be larger than the target contrast. While such a case gives an excessive contrast value as far as relating photointerpreter performance to scene contrast, it should still be a reliable quality measure of the scene. The majority of militarily significant targets can be classified in the first two groups, but a number of photographs do occur in the third category. A specific example of such a situation would be an underground missile complex located in a high contrast background of black mountains and snow. In this example, the P.I. would see a small density difference between the target (launch pad) and their surrounding (low target contrast) whereas the snow alternating with the black mountain would produce a much larger difference of density (large scene contrast).

Measuring the contrast as the average of the six largest density fluctuations occurring in the scene is also obviously independent of any large scale uniform exposure gradient.

3. Passband and Resolution

The fidelity with which each object point is reproduced in the image can be described by the intensity distribution of the image of one point, which is commonly called the "point spread function".* It is common practice

* This function and the others that follow are described in detail in Appendix II.

in optics and photography to use the Fourier transform of the point spread called the "optical transfer function" which, in general, is complex and a function of two spatial frequencies. However, for the remainder of this report, only the absolute value of the optical transfer function will be of concern and will be referred to as either the "modulation transfer function", "modulation function" or "modulation curve". Moreover, this report will only be concerned with the one dimensional modulation function resulting from a cross sectional cut through the origin of the two-dimensional modulation function and unless specifically stated to the contrary will be implied every time the words "modulation transfer function" are used.

The modulation curve can be measured for a system by photographing a set of test charts which have an intensity that varies sinusoidally with position, and in which the size of one cycle of the sine wave is different for each chart. The ratio of the contrast modulation (brightness difference divided by average brightness) of the image to that of the object is plotted as a function of spatial frequency (number of sine wave cycles per millimeter). This modulation curve is shown, for a typical system, in Figure 3.

Since sine wave test charts do not occur in aerial photographs, whereas edges do,* the mathematical relation of the line spread to the density trace of an image of an edge is, in practice, used to obtain the modulation curve.

In general, the modulation curve is a function of orientation, that is, the curve shown in Figure 3 could change, if the sine wave charts were rotated. While this variation occurs far off-axis for most cameras, for reason of simplicity it is ignored.

Two parameters were derived from the modulation curve for this study. These were first, the area under the square of the modulation function called the "equivalent passband," (N_e), and second, the "resolution,"

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* It might be thought that "points" or "lines" would be valuable as known object functions; however, any true point or line of finite intensity in the object scene will be undiscernable in the degraded image.

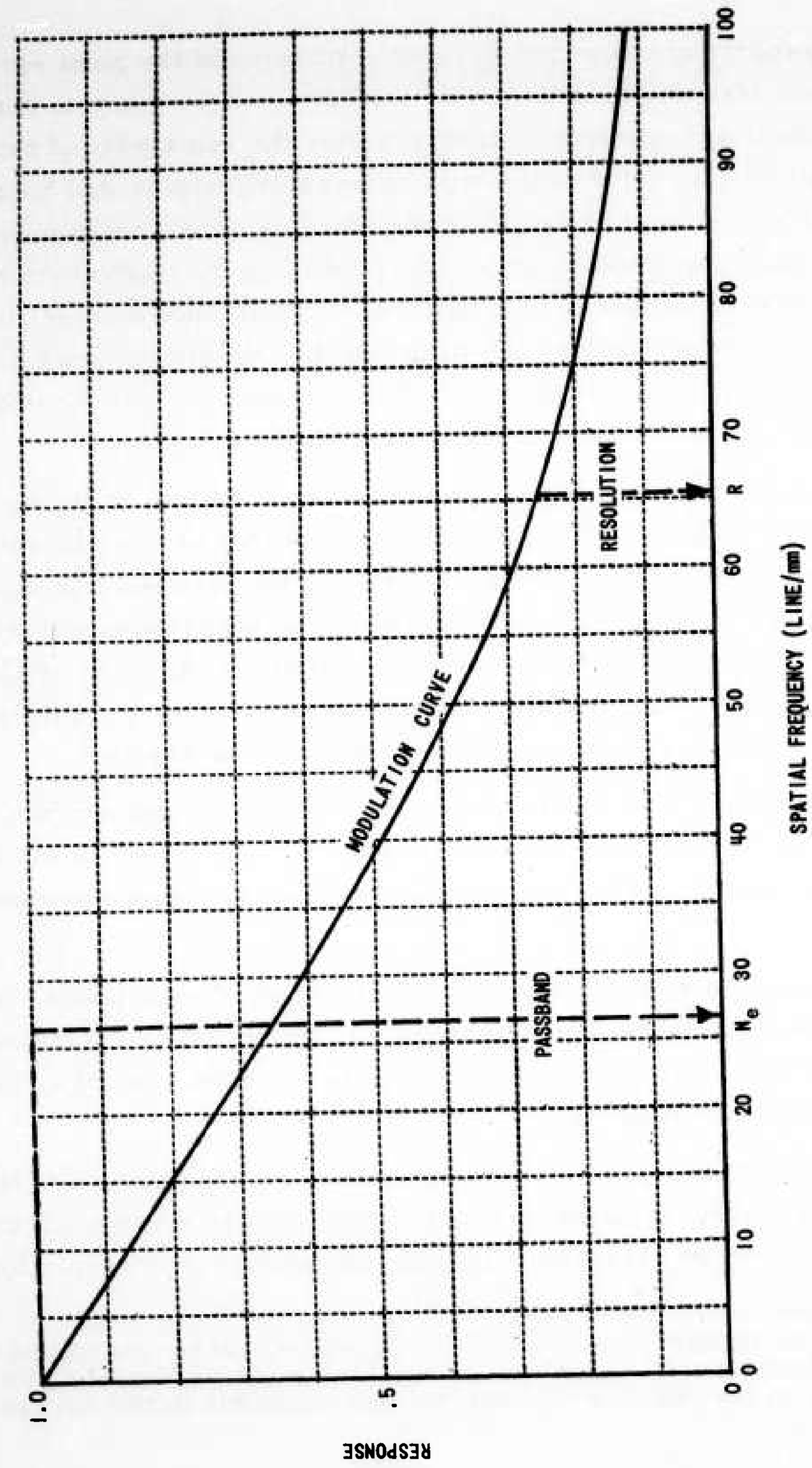


Fig. 3 TYPICAL MODULATION CURVE

R , defined as that frequency at which the transfer curve has dropped to 25% of its zero frequency value.

Because of a relationship between passband and resolution (discussed more fully in a later section), the numbers derivable from an edge trace, which will be used in describing the summary measure, will be resolution and the ratio of passband to resolution. Thus, it will be sufficient to discuss only the measurement and meaning of passband and resolution.

The passband and resolution numbers are obtained in the following manner:

(1) A sharp edge is scanned with a rectangular aperture in a microdensitometer and the density trace is recorded. (A sharp edge is one which is sharp on the original scene, i.e., edges of buildings, etc.)

(2) The edge data are smoothed to reduce noise which is present in the input. This is usually accomplished by a least squares fit of the data points to a polynomial. *

(3) With this smoothed data for the edge trace, the line spread function, $L(x)$ is calculated from the following formula:

$$L(x) = D'(x)\, 10^{\left(\frac{D(x)}{\gamma}\right)} \Big/ \gamma (\log_{10} e)\left(10^{\frac{D_1}{\gamma}} - 10^{\frac{D_0}{\gamma}}\right) \quad (3)$$

where $D'(x) = \frac{dD}{dx}$, $D(x)$ = density at position x, e = Napierian logarithmic base, D_1 and D_2 the end point densities of the edge trace and γ the slope of the photographic H-D curve. Auxiliary data of the development of the photograph furnishes γ for this calculation. However, calculations are made for five equally spaced γ's about the "true value" to check the dependence of the computed $L(x)$ on γ . In all calculations $L(x)$ has been insensitive to the value of γ .

(4) The passband*, N_e is calculated from:

$$N_e = \frac{1}{2}\int_{-\infty}^{+\infty} L^2(x)\,dx \quad (4)$$

---

* See Appendix II for all mathematical derivations of formulas used in this section and for a description of the data smoothing process.

(5) The transfer function, $\tau(\omega)$, is calculated from

$$\tau(\omega) = \int_{-\infty}^{+\infty} L(x) e^{i\omega x} dx \quad (5)$$

where ω is the angular spatial frequency. (6) In this program the value of $\omega/2\pi$ for which $\tau(\omega/2\pi) = .25$ is by definition the resolution of that particular scene.

All computations from steps (2) through (6) were performed on an IBM 704 computer. In the microdensitometer traces, the slit was parallel to the edge with a maximum possible error of one degree.

The edges were scanned first with an effective $5\,\mu$ x $380\,\mu$ slit and then by an effective $25.4\,\mu$ x $380\,\mu$ slit. If there were no changes in the shape of the edge traces, the larger slit size was used because of the lower grain noise. If there was a change in the shape of the edge trace, the smaller aperture trace was used as the raw data in the analyses of the pass-band and resolution.

4. Scale

Scale was not used as a physical variable, however it deserves special attention. When scale is discussed, confusion often arises since in reality two different scales are referred to. The block diagram in Figure 4 illustrates the problem. When an aerial photograph is acquired, the image size is related to the scene by the "photographic scale." When the image is to be interpreted, the image is normally increased in size for viewing, either by photographic enlargement or by optical magnifiers (or a combination). This latter magnification has been called the "viewing scale" for convenience.

Considering the viewing scale first, the purpose of the change of size is to present the image to the eye under optimum conditions. Clearly, the amount of magnification which is useful depends on both the target to be

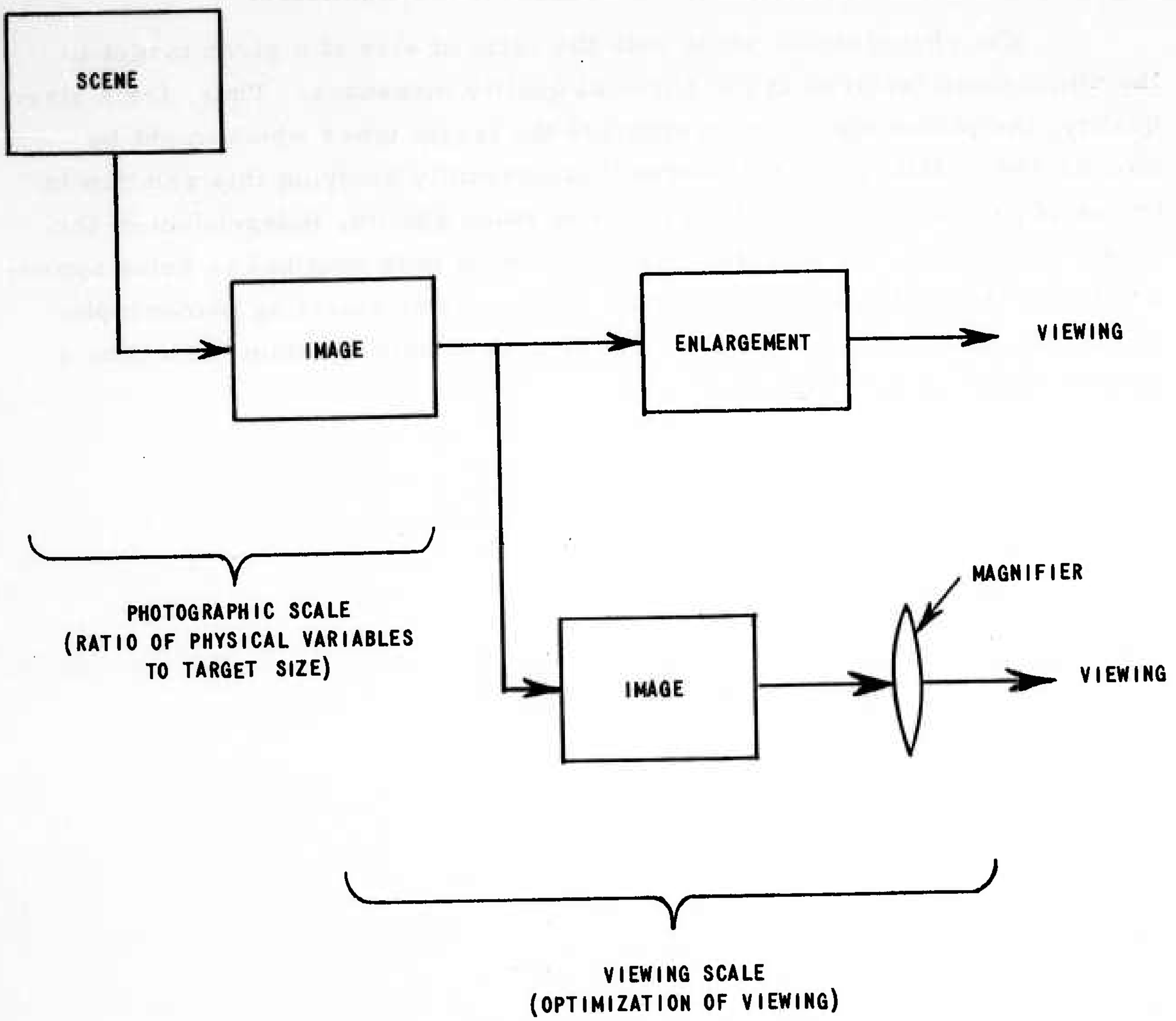


Fig. 4 TREATMENT OF SCALE

examined and the quality of the original image. The photointerpreter is the best judge of optimum conditions for each case, and is therefore allowed to vary the viewing scale by selection from a set of magnifiers.

The photographic scale sets the ratio of size of a given target to the dimensions involved in the physical quality measures. Thus, for a given quality, the photographic scale controls the target types which might be interpreted. (Minneapolis-Honeywell is currently studying this relation in terms of ground resolution.) In order to study quality, independent of the target type effect, the targets were selected on each original as being appropriate for the particular photographic scale. After selecting photographs at various scales, the photographic scales were held constant each time a given original was presented.

B. IMAGE MODIFICATION

A number of methods are available for image modifications. Table 1 lists several of these methods, and the parameter that each method primarily modifies, and whether the method enhances or degrades that parameter. Generally, these methods are not completely independent (i.e., method 4 also changes granularity slightly) and proper account of the interrelationships must be taken to obtain specific ranges of variables. This aspect is discussed in more detail in a later part of this section.

The last method, Spatial Filtering, was selected for the modification of the imagery in the final tests and is discussed in detail in Appendix III. The process of spatial filtering consists of transforming (by optical diffraction) a photographic image on a transparency into its spatial frequency components, filtering the resulting spectrum, and reconstructing a filtered image by a second transformation.

The passband and resolution can be modified by spatial filtering with appropriate filters. Granularity can be decreased by filtering out the higher frequencies which are not needed to form the filtered image, and can be increased by imaging the modified scene onto different films (2 in Table I). Contrast can be modified by two means. Increased contrast can be obtained by developing the image film to a high gamma. Decreased contrast can be obtained by dividing the total exposure into a uniformveiling exposure, and an imaging exposure.

TABLE I MODIFICATION TECHNIQUES

METHOD	MODIFIES	ENHANCE OR DEGRADE
1. DEFOCUS	τ	D
2. COPY ON GRAINY FILM	$G, (\tau)$	D
3. COPY WITH VEILING ILLUMINATION	C	D
4. COPY ON HIGH GAMMA FILM	C	E
5. SPATIAL FILTERING	τ, G	E OR D

C. SELECTION OF VARIABLE VALUES

To determine the functional form of the summary measure, as described previously, the necessary photointerpretive tests require input photographs in which the physical variables cover a wide range of values. This desired variation of physical parameters does not usually occur to any large extent in aerial photography taken with a small number of different cameras. The simplest solution, therefore, is to start with a limited supply of high quality aerial photographs and artificially vary the physical parameters in a controlled manner to generate desired ranges of variables.

The parameters to be varied are: contrast, grain, passband, and resolution. However, these variables are not completely independent. In order to perform tests with samples of photographs which are representative of the distribution which exists in real photographs, the ranges of the individual variables and their correlations must be taken into account.

Contrast is relatively independent of the other variables. A correlation with scale might be noted since higher altitude implies lower contrast and generally smaller scale. This correlation is weakened by the use of various focal length lenses (which decorrelates altitude and scale) and by natural weather variations (which introduces contrast change at one altitude). Therefore, for this study, contrast will be assumed to be independent of other variables. The range of contrast is taken to cover from barely detectable contrast to as high as normally observed in aerial photographs. This limits the range of scene contrast (C) to approximately 0.05 to 2.0.

In order to determine representative ranges and correlations of the passband, resolution, and grain variables, a number of lens-film combinations were considered with lenses at several focus settings (coarsely simulating normal focus errors and other errors, such as motion or vibration). The resultant values are plotted in Figure 5 with theoretical limits shown. Although the cases shown are by no means complete, ranges and correlations can be seen.

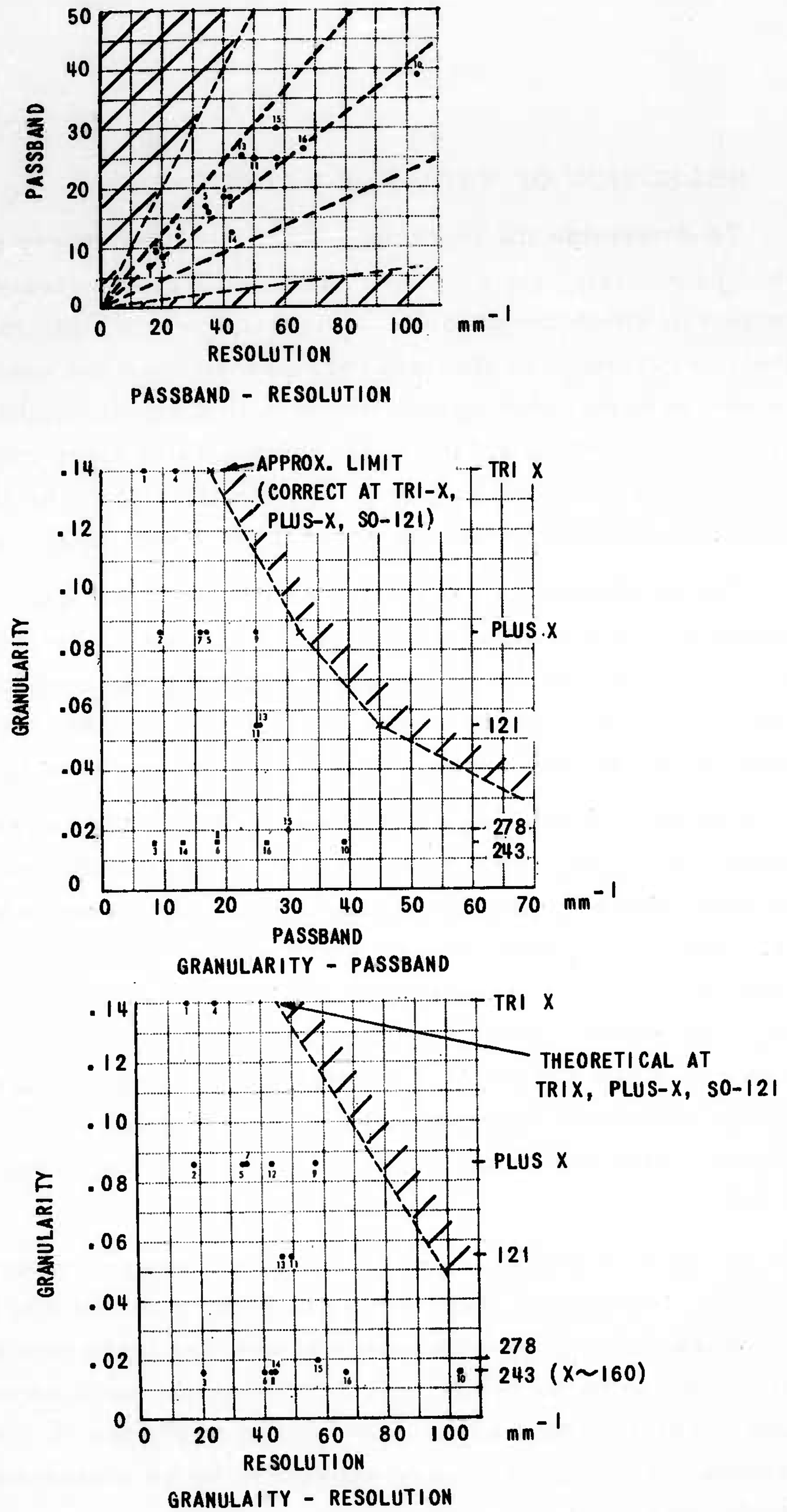


Fig. 5 VARIABLE CORRELATIONS

The granularity range is 0.01 to 0.15 and is typified by several common films. The correlation with passband and resolution is essentially one of setting an upper limit depending on σ. In practice, a low grain film would seldom be used with a poor camera system, thus tending to eliminate low passband and resolution at low σ. This cutoff is not shown, but was included in sampling.

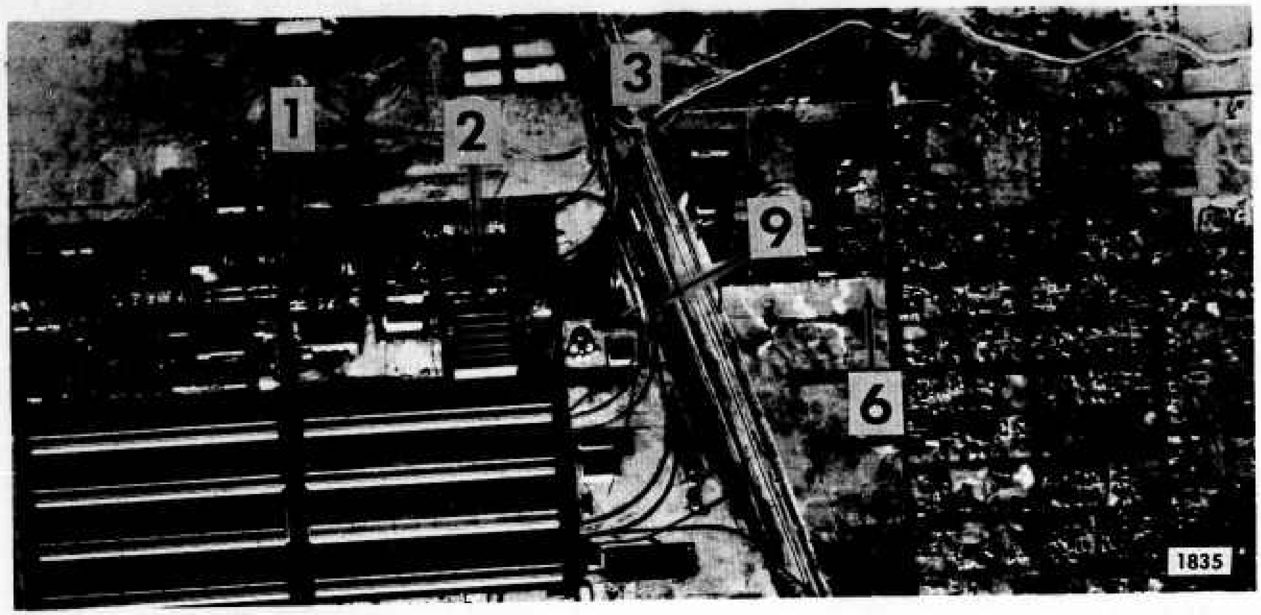
The relation of passband (N_e) to resolution (R) shows a definite correlation. It is possible to form a combination of these variables which provide two essentially independent variables. The resolution can be interpreted as a scale factor for the system modulation curve while the ratio of passband to resolution is a shape factor, which should be independent of R. Writing $K = N_e/R$, the value of K can vary in the range 0.25 to 0.60. While R is limited only by current lens design, a practical limit can be established for the test photographs. Since the high contrast resolution limit of the eye is the order of 5 to 10 lines/mm at normal viewing distance, the interpreter cannot make use of fine detail unless magnification is provided. Thus, the upper limit of the resolution used is chosen after the maximum available magnification is determined. Up to 12X magnifiers were provided. To cover a range from degradations nearly visible by eye to those visible only under maximum magnification, the range of R (the 25% point of the transfer function) was selected as approximately 4 - 50 lines/mm. This assumes a value of approximately 4 lines/mm for the low contrast resolution limit of the eye.

D. SELECTION OF PHOTOGRAPHS

All photographs were selected to fulfill the criterion of being areas of military significance. These areas include industrial facilities, railroad and storage facilities, ships and pier facilities, military airfields, radar stations and missile complexes. Scenes with various scales were selected for each of the above general areas. Because of a shortage of appropriate scenes, it was necessary to choose a number of classified films.

Ten targets were chosen for each original scene and ground truths established by the concurrence of three experienced photointerpreters. All targets were specific objects which could be identified in the unmodified photographs but which became progressively unrecognizable with increasing degradations. Checks by several photo-analysts indicated that all targets were identifiable on the highest quality scenes, none were identifiable on the poorest quality scenes, and on an average over all the scenes, approximately fifty percent were identifiable.

Figure 6 is part of an enlargement of a scene used in the determination test. Directly below the photograph is a list of the exact target present.



ACTUAL TARGETS

1 AIRCRAFT
2 MOBILE CRANE
3 SAWDUST BURNER
6 LUMBER YARD
9 FLAT CAR (S)

Fig. 6 A TYPICAL DETERMINATION SCENE WITH A LIST OF THE ACTUAL TARGETS

III. TEST PROGRAMS

This section contains the specific details and results of two experimental tests. The first test, denoted pretest, was smaller than the second which was called a determination test. The purpose of the pretest was to refine the measuring techniques and the image alterations, and to obtain an indication of the dependence of the summary measure on the photographic variables. The determination test was to determine the specific form of the summary measure.

A. PRETEST

Ten scenes containing military targets were selected. Each photograph was reproduced with ten different combinations of the four physical variables. This resulted in a total of 100 different combinations spaced over the range of each of the four variables. The ten variations for each of the ten scenes were picked at random from 375 possible combinations (i.e., 5 grains x 5 contrasts x 5 resolutions x 3 passband-to-resolution ratios).

In order to simulate the real photographic acquisition process, original 9" x 9" positive transparencies were used and the modifications were introduced as the 70 mm negatives were produced. By contact printing, two positives were made from each negative transparency. Special overlays were xeroxed onto the positive transparencies producing 200 photographs, 100 (with a coordinate system superimposed) to be used in the modified free search task and 100 (each with ten circled targets) to be used in the identification task.

This section gives the experimental details of how the variations of variables for the 100 photographs were produced, the specifics of the modified free search task and the identification task, and an evaluation of the pretest.

1. Photography

The modifications were produced by aperture filtering with a Grover-View camera equipped with a Graflex lens. The apertures used to obtain the three passbands were: a small aperture, a larger aperture and an annular neutral density disc inserted in a large aperture. The small aperture reduced the aberrations of the lens, thus a sharp point spread should be produced and a large passband-to-resolution ratio should be obtained. With the larger aperture, a sharp point spread is still expected due to the center of the lens but the aberrations of the edges of the lens should enlarge the tail of the point spread; hence a small passband to resolution ratio should be obtained. The annular neutral density filter should produce an intermediate effect on the point spread; therefore, this aperture should give an intermediate passband to resolution ratio.

With a given aperture, resolution was controlled by defocussing the lens. To maintain as much reproducibility as possible, a sine wave test chart was photographed at various distances from focus with the three apertures. From subsequent measurements, graphs were obtained of these modulation functions. Resolution as a function of distance-out-of-focus was also determined. Note that although defocussing the lens lowers both the resolution and passband considerably, it produces only a slight change in the passband to resolution ratio.

A table was constructed with the three aperture and the distances-out-of-focus versus resolution information. It was felt that from this table, five different resolution values could be obtained for each of the high, medium and low passband to resolution ratios described above. Because of mechanical instability which places an upper limit on the obtainable resolution a complete range of variables was not expected, but it was felt that the range of resolution and passband to resolution ratio would be sufficient for the purposes of the pretest. The actual ranges produced on the pretest were: resolution, 5-20 lines/mm; passband/resolution, 0.35-0.80. The actual value of resolution and passband to resolution ratio were measured for each image in the manner described in a previous section. To achieve sufficient control of the physical parameters for the Determination Test, a more stable apparatus was required.

Five levels of contrast were obtained by veiling, i.e., a uniform exposure and the image of the scene were superimposed on the same film.

This veiling exposure was theoretically adjusted in relationship to the total exposure, to give ratios of the largest density difference of the 70 mm copy to the maximum density difference of the original 9" x 9" of approximately 1.0, 0.75, 0.50, 0.25 and 0.10. In the actual 70 mm negatives, some adjustments in the veiling exposure had to be made at the lower contrast values because of camera flare.* Measurements following the previously described procedure revealed that the range of contrast values were 0.50-0.80. This veiling procedure to lower contrast gave a good range of values and hence was satisfactory for use in the determination test modification.

Grain was controlled by using five different films: SO-278, Panatomic X, Plus X, Super XX and Tri X. These 70 mm negatives were copied with a contact printer to create positive transparencies on SO-278. It was hoped that this procedure would eliminate any bias which a photo-interpreter might have if he preferred to view one type of film (due to color difference, for example). The granularities of each of the positives were measured at the average density of the picture and not all at a fixed density as is the procedure given in Kodak's film data book. The calculation of σ followed the procedure given in a previous section. Actual results indicated there were no grouping according to film types but a rather arbitrary distribution which had the range 0.025 - 0.10.

Analysis of the granularity data and subsequent experiments showed that the process of creating a positive transparency by contact printing from a modified negative tends to compress the granularity scale and creates a "nonwhite" grain noise spatial frequency spectrum. Therefore, the determination test image modification procedure had to eliminate the contact printing process.

2. Test Procedure

Perhaps the most realistic photointerpretation task that could have been used is free search. For this task, the interpreter searches

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* Camera flare also places an upper limit on the obtainable contrast.

the photograph and locates and identifies any targets he finds. Unfortunately, since the total number of responses is not specified in any instruction, the interpreter is left to choose for himself whether or not to respond to doubtful targets. This creates a conflict between accuracy and completeness. To increase accuracy, one should respond only when he is certain, while to increase completeness one should respond to everything. Such a set of conflicting criteria would result in an increased error variance and could mask the true effects of experimental variables. To establish a definite accuracy criterion, two tasks were chosen both involving a specification of the number of targets on each photograph. These tasks will be referred to as identification and modified free search.

For the identification task, ten targets were annotated on each photograph. The interpreter was required to identify each target, selecting his answers from a key containing these target identifications plus 10 targets which did not occur in the scene.

In the modified free search task, each interpreter was required to locate and identify the same targets used in the identification task. In other words, the interpreters searched each photograph and located ten targets appearing on a target key. This task is somewhat more realistic than identification, since the photographs are not annotated, but the task requires more time.

For each task, answer sheets were provided for each photograph. Table 2 presents a sample answer sheet for the identification task. Answer sheets for the modified free search task contained the same material and two extra columns to give the x and y coordinate of the targets. In addition to reporting the information in the answer columns, subjects were instructed to record their confidence in each target identification. Confidence was defined as the percentage of time an identification with a given rating would be correct, such that identifications rated near zero would, almost never be correct and identifications rated near one hundred would almost always be correct.

TABLE 2 TYPICAL ANSWER SHEET FOR THE PRETEST IDENTIFICATION TASK

PHOTO NUMBER	TARGET NUMBER	MAGNIFICATION AID
a. FIVE RAILROAD CARS ON SIDING NEAR SUPPLY DEPOT.	1. ______	______
b. A SEWAGE TREATMENT PLANT.	2. ______	______
c. REVETED BLAST WALLS FOR PROTECTION FROM AIRCRAFT JET EXHAUSTS.	3. ______	______
d. ONE SINGLE ENGINE, HIGH WING AIRCRAFT.	4. ______	______
e. FOURTEEN SEMITRAILER FUEL TRUCKS IN A POL AREA.	5. ______	______
f. AMMO/BOMB STORAGE BUNKER AREA.	6. ______	______
g. THE REMAINS OF A WRECKED C-47 AIRCRAFT NEAR END OF RUNWAY.	7. ______	______
h. A BULLDOZER GRADING AREA OFF END OF RUNWAY.	8. ______	______
i. A C-130 TRANSPORT WITH ONE ENGINE REMOVED.	9. ______	______
j. A FUEL TRUCK BEHIND A SWEPT WING AIRCRAFT.	10. ______	______
k. A B-52 WITH RIGHT WING REMOVED.		
l. A FUEL TRUCK ON AN APRON.		
m. TWO ENGINE TEST STANDS.		
n. A SKEET RANGE.		
o. A C-133 TRANSPORT.		
p. A POWER SUBSTATION NEAR ENTRANCE TO THE BASE.		
q. A TENT CAMP ON THE UNUSED RUNWAY.		
r. SEVERAL RAILROAD CARS ON A SIDING NEAR JET ENGINE TEST STANDS.		
s. A FUEL TRUCK ON THE MAJOR RUNWAY.		
t. AN ELECTRIC POWER TRANSMISSION LINE THROUGH THE WOODS.		

Inspection of Table 2 reveals that all targets in the key consist of specific objects. This type of target designation was necessary to limit the number of correct identifications in the modified search task, thus maintaining ten identical targets in both pretest tasks.

Subjects were supplied with 3, 8, and 12-power magnifiers.* They were instructed to use any or all three of these magnifiers in making their identifications. Subjects were not given any photointerpreter reference keys, so were not able to compare images with standard reference targets.

The modified imagery was used in the testing of nine photointerpreters from Fort Holabird, seven from Fort Meade and four from USAPRO. All subjects from Fort Meade and USAPRO had several years experience in photointerpretation. Those from Fort Holabird were completing the Army photointerpretation course and had served in a number of previous experiments. The photographs were randomly assigned to the photointerpreters with the restriction that an interpreter should view each of the ten basic scenes only once. This restriction was necessary to control learning effects which would result from repeated viewing of a single scene.

Five interpreters from Holabird, four from Meade and one from APRO worked on the identification task. Four interpreters from Holabird, three from APRO and three from Meade were presented with the modified free search task.

3. Results

In the interpretation tests, the primary results are those relevant to the selection of a photointerpreter task and photointerpreter test methods for the determination test. The accuracy scores, mean confidence rating and physical measures for the pretest are tabulated in Appendix IV.

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* The resolution of the magnifiers was measured as 17, 18, 17 lines/mm respectively in the virtual image. Since these are more than three times the resolution of the normal eye, the magnifiers should cause less than 5% error in the net resolution.

The correlation among the physical variables and the performance measures are given in Table 3. The elements of this matrix, r_{xy} , are Pearson's product-moment coefficients of correlation. The magnitude of r gives a measure of the "strength" of correlation between two variables. (The values of r range from -1 to +1.) The best possible prediction of one variable (y) from a known value of another variable (x) is obtained from the equation:*

$$y = r\sigma_y \sigma_x^{-1}(x - \bar{x}) + \bar{y} \tag{6}$$

where $\bar{x}$ and $\bar{y}$ are the means of x and y , σ_x and σ_y are the standard deviation of x and y , and r is the corresponding element in the matrix of Table 3.

The multiple R is given only for the accuracy scores of the identification and search task. The square of the multiple R is a measure of the variance in the accuracy scores associated with or determined by the variance in the accuracy scores associated with or determined by the variance of a linear combination of the four chosen quality parameters.

The low multiple R for the linear combination of physical variables, plus the scatter of the data which becomes apparent when scattergrams are plotted indicate that further effort toward deriving a preliminary summary measure was not warranted. A useful summary measure should account for at least 50% of the variance, implying a multiple R of over 0.7.

The correlation between the average search score and average identification accuracy scores across scenes is 0.86. The correlation between search and identification accuracy scores across the 100 photographs is 0.32.

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* Guilford, J.P. Fundamental Statistics in Psychology and Education McGraw-Hill Book Co., Inc. 3rd Edition p. 367 1956

TABLE 3 CORRELATION MATRIX FOR PRETESTS

			Correlations					
	Mean	Sigma	Contrast	Grain	Passband/ Resolution	Resolution	Confidence	Multiple R
Contrast	0.35	0.17		0.34	-0.24	-0.03		
Grain	0.44	0.15			0.03	-0.09		
Passband/ Resolution	0.59	0.09				-0.05		
Resolution	9.7	5.3						
Search:								
Accuracy	3.3	1.7	0.41	0.01	0.12	0.09	0.51	0.51
Confidence	37.	21.	0.28	0.06	0.04	0.09		
Identification:								
Accuracy	4.4	2.2	0.32	0.06	0.01	0.17	0.32	0.39
Confidence	42.	21.	0.25	0.03	-0.08	0.06		

4. Discussion of Results

While the higher multiple correlation would indicate that the search task might be more appropriate for the determination tests, it was also ascertained that mean time per response for that task was more than double that found for the identification task. As photointerpreter time was severely limited, a determination test of adequate scope could only be carried out with the identification task. Support for the choice of the more feasible task was provided by the high correlation found between the two tasks on the pretests.

The choice of the identification task also permitted modification of the target descriptions on the answer sheets. These descriptions had been made appropriate to both of the pretest tasks, but the need for unique targets in the modified search tasks required that excessive location information (e.g., "two soldiers near a truck") be provided. Descriptions of this type were not used in the determination tests.

The use of target keys containing only 20 targets was found to be another limiting factor in the pretest. As 10 of the 20 targets were the correct responses and others could be readily eliminated from consideration, there was more opportunity for making correct guesses than was desirable. It was therefore decided that the target keys for the determination phase should contain a larger number of incorrect alternatives which would help to prevent the occurrence of correct responses through the process of elimination.

During the pretests, many of the photointerpreter subjects indicated a desire for photograph scale information and target reference keys. The determination test plans therefore included the provision of these data and materials, which were not provided in the pretest.

B. DETERMINATION TEST

The number of photographs and physical variations were determined by time considerations and availability of photointerpreters. It was decided to make one thousand photographs, twenty-five photointerpreters each viewing forty photographs. The quality of the forty scenes ranged over three values of passband-to-resolution ratios, five resolutions, five contrasts and four granularities. From these 300 possible combinations of variables, 250 combinations were selected as most representative of real aerial photographs. Four scenes were produced with each combination of parameters. The selection of scenes for each combination was random but restricted such that each of the 40 scenes was reproduced 25 times. These modified photographs were used in interpretive tests and the results analyzed. This section contains the image modification procedures, a description of the interpretive tests, and the results of the determination test.

1. Photography

The photographs used in the determination test were obtained by the modification process illustrated in Figure 7. The forty scenes, having a wide range of militarily significant targets, were originally in the form of 9" x 9" positive transparencies, and they were reduced to approximately 3" x 3" negatives. These negatives were secured to an aluminum frame

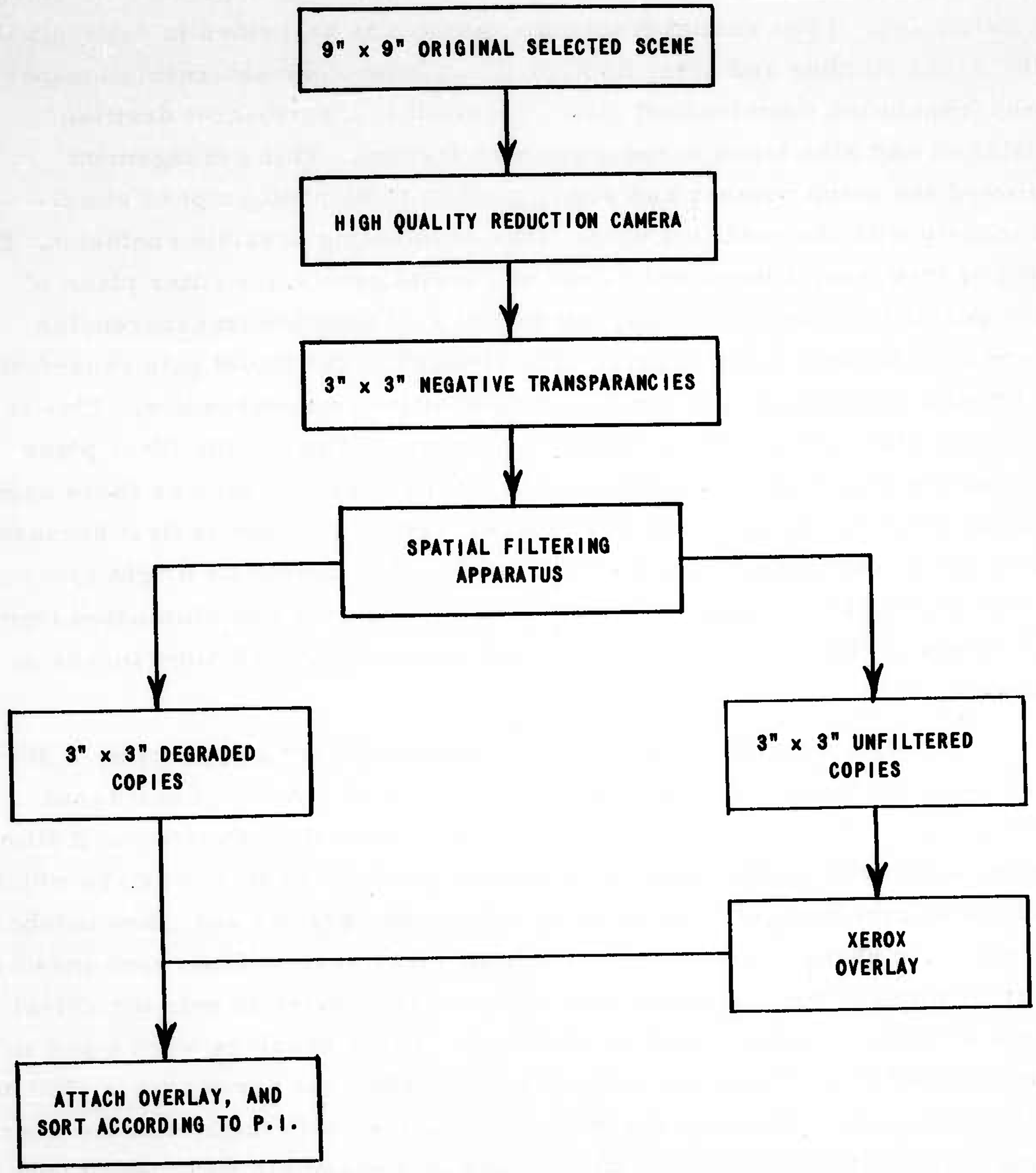

Fig. 7 PRODUCTION OF DEGRADED SCENES FOR THE DETERMINATION TEST

which could be rapidly inserted into a spatial filtering apparatus for image modification. (The spatial filtering apparatus is described in Appendix III.) The scene number and setup number (i. e., film-contrast-resolution-pass-band/resolution combination) were inscribed in a scribecoat drafting material and also taped to the aluminum frames. This arrangement allowed the setup number and scene number to be photographed simultaneously with the modified scene; thus eliminating possible confusion. The spatial frequency filters were used in a liquid gate in the filter plane of the spatial filtering apparatus, but the 3" x 3" negative transparencies were used without a liquid gate. The absence of the liquid gate caused no noticeable modification in the resulting positive transparencies. This is expected since the phase variations are more critical at the filter plane than at the object plane for filters of a low pass nature such as those used on this project. Streaks and dust specks were a problem at first because their image overlapped targets but were found to appear as bright spots in a high pass filtered image and hence could be located and eliminated from the system. This arrangement of liquid gates minimized time losses in changing scenes.

With a filter and scene in the spatial filtering apparatus, a 3" x 3" modified positive transparency was produced. A set of unfiltered photographs, one for each scene, was also produced on Panatomic X film. These unfiltered photographs were used to produce master overlays which had ten selected targets identified by Zip-a-tone arrows and inked numbers. Twenty-five xeroxed copies were made on clear acetate from each master overlay since it was impractical to xerox arrows directly onto the aerial films because of natural curl of the films. These overlays were taped to the modified 3" x 3" positive transparencies after the arrows were matched with the targets. These positive transparencies, with their attached overlays, were framed with cardboard. When this ensemble was viewed with a light table it was impossible to distinguish between the four types of film which were used in the determination test, i. e., it eliminated all curl and covered color variations of the base material. This arrangement also circumvented the grain problems encountered in the pretest by eliminating all contact printing processes.

The four granularities were controlled by using four different types of film: SO-278, Panatomic X, Plus X and Tri X. The range of granularity measurements were from approximately 0.03 to 0.15 and were obtained in the following manner.

Approximately 20 scenes for each of the four films types used in the determination test were randomly selected from the 1000 photographs and granularity values were calculated as described in Section II. A plot of σ as a function of the average density at which σ was measured is plotted in Figure 8. The graphs of Figure 8 clearly reveal that the four types of film form separate groups. It was assumed that the curves of Figure 8 correctly express the granularity measurements of the 1000 photographs. Hence, the granularity values for the particular films used in the determination test were assumed to be the average σ in Figure 8, evaluated at a density of 1.2. The density of 1.2 was selected as the average density of the thousand photographs, this being the average density of the randomly selected scenes used to obtain Figure 8. Since all film of a given type was exposed and developed under identical conditions, the above assumption should be valid.

The values of σ for granularity are somewhat less than those published by Kodak in their film data book for the films used, when the effect of scanning aperture size is taken into account. Communications with personnel at Kodak and Dr. O. H. Schade of RCA indicate that the film data book values of σ may be too large, accounting for this discrepancy.

The five contrast levels were obtained by veiling exposures in a manner identical to the procedure described in the pretest section. Actual contrast values for each of the thousand photographs were in the range of 0.05 to 2.2.

The fifteen combinations of resolution and passband-to-resolution ratios were controlled by using fifteen spatial frequency filters. Three master filters were made by aperture filtering. The passband-to-resolution ratio for these master filters were adjusted to give approximate

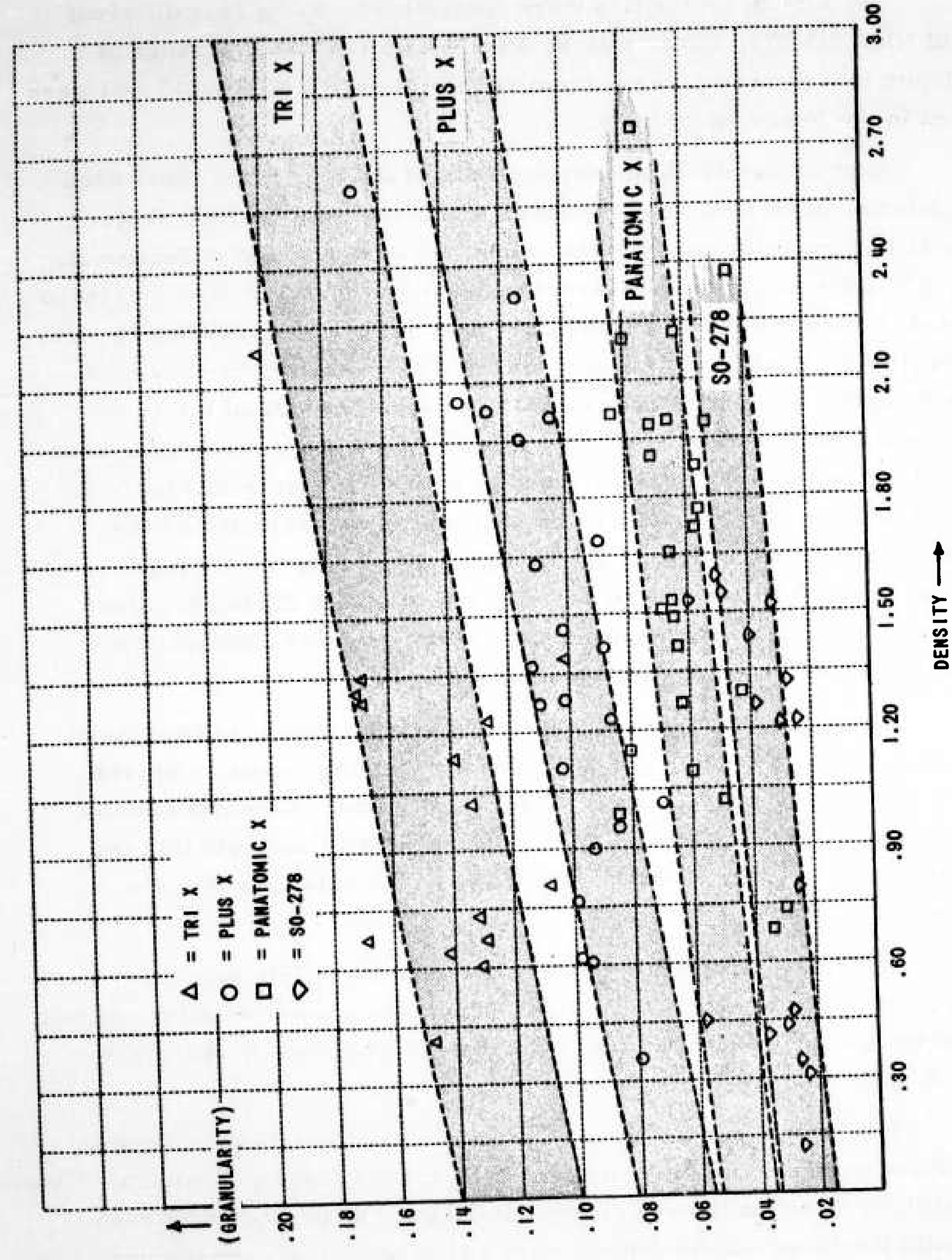

Fig. 8 GRANULARITY VS. DENSITY

values of 0.6, 0.45, and 0.3. The five levels of resolution were obtained by photographing the master filter at five different scales. Following the procedure described in Section II, the exact values of the resolution and passband-to-resolution ratios were obtained for the filters and are shown in Table 4.

Fifty film-filter combinations were selected from a group of sixty possibilities. Ten combinations were eliminated by comparing the resolution and passband values with the theoretical values given in Figure 5. The expected resolutions for a given passband-to-resolution ratio were 50, 35, 20, 10 and 5 lines/mm. The ten film-filter combinations deemed less likely to be obtained in real photographs are: low resolution on fine grain film and high resolutions on coarse grain films.

Measured values of passband-to-resolution ratio were in the range 0.29 to 0.55 while resolution values were in the range of 4.0 to 18.0 lines/mm. The calculations of these two measures are described below.

The values of passband N_e and resolution R were obtained by prediction from the modification process and checked by determining the values for a random sample of the modified photographs by the technique described in Section II and Appendix II. If the original photographs were of high quality compared to the desired modified images, the values of N_e and R for a given modified image would have been identical to those listed in Table 4 for the filter used in the particular modification. However, it was found that when the highest quality original scenes available were selected, the quality was far from high enough for such an assumption. Therefore, the modulation curve of the original had to be taken into account.

One or more edges were selected on each original scene, and microdensitometer scans were made of all selected edges. The procedure described in Appendix II was used to extract the line spread functions and modulation functions for the original scenes. The raw scan data were smoothed by a least squares fit to a seventh degree polynomial, considering

TABLE 4 SPATIAL FILTERS USED IN DETERMINATION TEST

FILTER #	(PASSBAND/RESOLUTION)	25% POINT RESOLUTION (LINES/mm)
1	0.66	57.0
2	0.63	39.0
3	0.62	22.6
4	0.56	9.4
5	0.62	5.1
6	0.40	59.3
7	0.40	39.2
8	0.40	20.6
9	0.39	10.0
10	0.42	5.0
11	0.30	57.5
12	0.27	37.4
13	0.26	17.4
14	0.30	10.0
15	0.31	4.7

errors in both the function and its derivative as significant.* Since it is the amplitude transmission function whose spectrum is modified in the spatial filtering system (see Appendix III), the appropriate relation of this function to the measured density must be used in the computation of the modulation function. From the definition of density (D) and amplitude transmission (T_A) one has:

$$D = -2 \log T_A \tag{7}$$

Comparing this equation to the film response (Hurter-Driffield curve) used in Appendix II:**

$$D = \gamma \log E \tag{8}$$

it can be seen that application of the method of Appendix II, assuming a gamma γ of -2, and identifying E with T_A provides the desired modulation curve. This procedure was used to arrive at the N_e and R values to be expected for each original modified by the use of each filter.

Two questions arise from this prediction process; first, how valid is the linear theory for degradations which occur in several steps, and second, how well do the predicted values agree with measurements of the modified photographs? To answer the first question, one can examine the problem on a theoretical or an experimental basis. Aerial photographic negatives were contact printed to produce a 9" x 9" positive transparency which was then reduced to a 3" x 3" negative which is used as the "original" for modification. If the primary degradation occurred in the contact printing, then the linear theory should be applicable. If this is not the case, then as the linearity approximation fails, different edges within

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* A fifth degree polynomial was also used, and little difference was found.

** See Appendix II.

an original should yield different modulation functions through the above procedure.* Thus, scanning several nearby edges within the format of one original allows this aspect to be checked. Table 5 shows the R values derived for several edges within one format. It can be seen that the difference within the format is small and can be considered to be well within the errors inherent in the noise removal process.

TABLE 5 RESOLUTION VALUES FOR DIFFERENT EDGES IN THE SAME SCENE

Original Scene	Resolution R in lines/mm
10A	10.4
10B	12.2
10C	12.2
10D	12.6

To answer the second question, approximately 50 modified images were selected and edges scanned. The selection was made so as to sample cases from all filters, although more cases of high and low (N_e/R) values were chosen than those of the middle class. It was found that the cases in which the the (N_e/R) ratio was predicted to be high, good agreement was found, while in cases predicted to be low the data smoothing process plus the effect of errors in the determination of the total density difference across the edge (shown in the numerical example in Appendix I) had the effect of raising the computed (N_e/R) ratio as well as causing larger fluctuations in the determination of R values, than for other cases. Because of the large errors in the computed (N_e/R) values the most reliable test of the prediction process is the value of R .

Figure 9 shows the correlation of measured and predicted values for a number of modified images. Good agreement is shown by the grouping of points along the 45° line (i.e., R measured = R predicted) with

* One might also expect a difference in modulation function across the format of the original due to the variation in lens quality with field angle. However, the lens effect depends only on position and varies slowly across the format, while the nonlinearity depends on density difference and average density value even for nearby edges, allowing the effects to be separated.

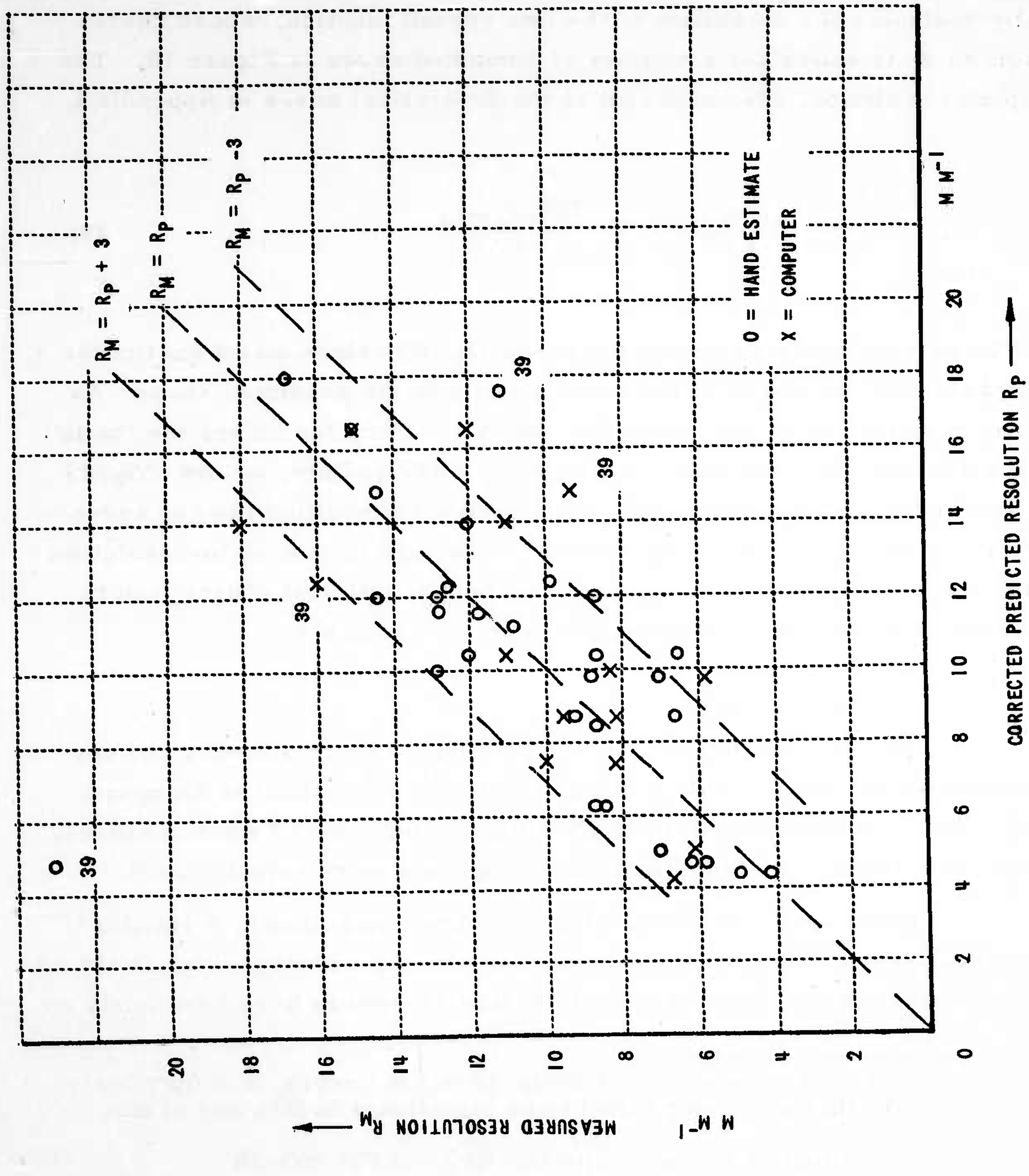

Fig. 9 CORRELATION OF MEASURED AND PREDICTED RESOLUTION

about a ± 3 line/mm error.* In a number of the cases shown as O, the measured value of R was obtained from the determination of the maximum of the density gradient as described in Appendix I. This process essentially evaluates the maximum of the line spread function, whose correlation to R is shown for a number of computed cases in Figure 10. The empirical relation, also apparent in the theoretical cases in Appendix I, is:

$$R = \frac{[L(x)]_{max}}{1.45} \cong \frac{[D'(x)]_{max}}{1.45 \Delta D} \tag{9}$$

The only check made on the predicted (N_e/R) values was a qualitative comparison of the shape of the density trace to the predicted shape. As shown in Appendix I, the lower the (N_e/R) value, the longer the "tails" of the density trace become. Rating high, intermediate, or low (N_e/R) on this basis, approximately 65% of the sampled modified images agree with the predicted values. Agreement of the high passband-to-resolution ratio cases with computer results, and checks with test charts lead to the conclusion that the prediction process is acceptable.

2. Test Procedures

The determination test was performed by 18 students and one instructor from the Air Force image interpretation school at Sheppard AFB. The test was designed for 25 subjects, but only 19 were available. Thus, only 760 of the 1000 modified photographs were actually used.

Each subject was provided with three magnifiers, a standard PI reference key** and a set of 40 answer sheets, corresponding to the 40 scenes. The magnifiers were the 3, 8, and 12 powers used previously on

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* Scene 39 accounts for 4 of the greatest errors, and may indicate that nonlinear effects are significant in this one scene.

** Consolidated Photointerpreter Key AFM 200-28

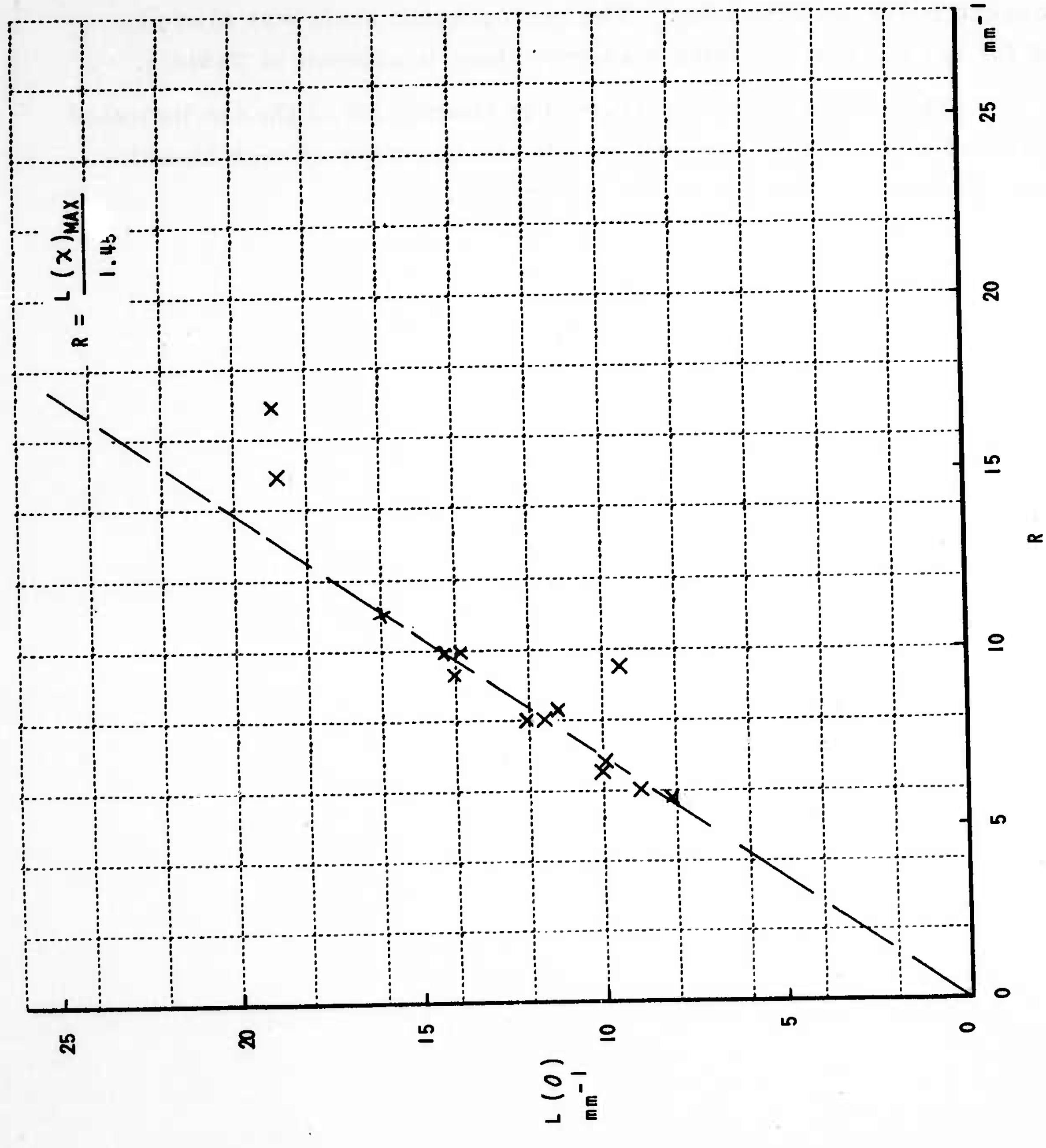

Fig. 10 CORRELATION OF LINE SPREAD MAXIMUM AND RESOLUTION

the pretest. Subjects were instructed to use any or all of the three magnifiers as desired. Each answer sheet consisted of a target test containing 10 correct and 40 incorrect target alternatives, a column for recording the identifications of the ten indicated targets, and a column for recording confidence in the identification. The photographic scale was also provided for each scene. A sample answer sheet is present in Table 6.

The subjects were instructed to identify all of the ten indicated targets and to record their confidence in the accuracy of each identification. Confidence was defined in the pretest.

TABLE 6 SAMPLE ANSWER SHEET FOR DETERMINATION TEST

PI ______ PHOTO # NAME ____________________ TIME STARTED ________ TIME FINISHED ________

I. AIRCRAFT

1. A/C - UNDIFFERENTIATED
2. SINGLE ENGINE
3. TWIN ENGINE
4. FOUR ENGINE
5. DOUBLE RUDDER
6. TWIN BOOM
7. BUTTERFLY TAIL
8. SWEPT WING
9. AMPHIBIAN
10. A/C WITH WINGS FOLDED
11. WRECKED A/C
12. 2-BLADED HELICOPTER
13. 3-BLADED HELICOPTER

II. AIRFIELD EQUIPMENT

14. OPERATIONS BUILDING
15. CONTROL TOWER
16. ANTENNA ATOP BUILDING
17. RADIO ANTENNA GROUND ARRAY
18. COMPASS ROSE
19. INNER MARKER BEACON

III. STORAGE FACILITIES

20. BUNKER
21. WAREHOUSE
22. SPECIAL WEAPONS STORAGE
23. TANK(S) - UNDIFFERENTIATED
24. TANK FARM
25. POL TANK(S)
26. GASOMETER(S)
27. ELEVATED TANK(S)
28. EARTH COVERED TANK(S)
29. SPHERICAL TANK(S)
30. OPEN STORAGE
31. LUMBER YARD
32. COAL PILES

IV. CONSTRUCTION & MOBILE EQUIPMENT

33. MOBILE CRANE
34. POWER SHOVEL
35. BULLDOZER
36. EARTHMOVER
37. TRUCK(S) - UNDIFFERENTIATED
38. SEMI-TRAILER TRUCK(S)
39. STAKE BODY TRUCK(S)
40. PICKUP TRUCK(S)

IV. CONSTRUCTION AND MOBILE EQUIPMENT (CONT.)

41. POL TRUCK(S)
42. FUEL TRUCK(S)
43. VAN TYPE TRAILER
44. ONE-TON TRAILER

V. MISCELLANEOUS

45. BUILDING-UNDIFFERENTIATED
46. SEWAGE TREATMENT PLANT
47. WATER TREATMENT PLANT
48. BORROW PIT
49. INCINERATOR PIT
50. LAGOON

TARGET #	CONFIDENCE
1. ______	______
2. ______	______
3. ______	______
4. ______	______
5. ______	______
6. ______	______
7. ______	______
8. ______	______
9. ______	______
10. ______	______

SCALE 1/10,000

3. Results

The raw scores for the 19 interpreters and the values of the four physical variables for each of the 1000 modified photographs are tabulated in Appendix V.

Histograms of the distribution of interpreter scores are shown in Figure 19 for each original scene and Figure 20 for each interpreter (See Appendix V). The mean score for each interpreter is shown on the figure. The mean score for all interpreters is only 2.2, and as can be seen from the histograms, nearly all scores are grouped closely at the low end of the scale. The only exception is the instructor whose mean score of 3.67 is almost double the average score.

Discussions with instructors at S.A.F.B. revealed: a) The training course at S.A.F.B. consists mostly of the basic theory necessary for photointerpretation with less emphasis on actual target identification, and b) all students completing the training course must have experience at an operational installation for one year before they can obtain a PI rating.

The student subjects also indicated (in writing and in conversations with them): a) their experience had consisted mainly of work with stereographic materials, b) in many cases, they lacked familiarity with particular target classes and with certain targets within each class, and c) the nomenclature was foreign. The greatest difficulty was encountered with missile sites, and army facilities and equipment.

Responses from the participating instructor indicated he was generally familiar with the nomenclature and although a range of physical quality was sampled in the photographs, the majority of the scenes which he observed were of lower quality than those normally used in photointerpretation.

In general, the discussions at S.A.F.B. suggested that the 18 participating students did not have the level of experience necessary for the determination tests.

Prior to any analysis with the data, answers were rescored on a less specific level, i.e. instead of considering the specific targets (e.g. POL tank) the answers were scored under a general classification (e.g. presence of storage tanks). This procedure raised the level of the scores but did not improve the distributions because most subjects now generally were always correct on the easy targets but still incorrect on the difficult or unfamiliar ones. After this attempt at rescoring, analyses were carried out to determine if any meaningful results could be obtained from the raw data tabulated in Appendix V.

Product moment correlations were computed between all variables as in the pretest. The correlation matrix for the determination test is given in Table 7. The correlations between physical variables indicate that the desired relations were achieved reasonably well, the two strongest correlations being granularity and passband-to-resolution ratio with resolution. These correlations were expected because high grain films were not used at high resolutions and because the limited quality of available originals made it difficult to achieve low passband-to-resolution ratios at high resolution. Low correlations were found between the accuracy scores with the individual variables and a low multiple R was found between accuracy and a linear combination of the physical variables. The multiple R = 0.36 indicates that only 13 percent (i.e. R^2) of the variance in the accuracy scores is accounted for by the physical variables.

To obtain at least a rough indication of the terms which should be considered in further summary measure studies, and in fact to determine whether a summary measure can be expected to exist, the data were divided into groups having approximately equal physical measure values. Contrast and resolution were divided as low, medium and high, while passband-to-resolution ratio and granularity were divided simply as low or high. The accuracy scores achieved on photographs with approximately constant physical quality are plotted in Figure 11. While in a few cases peaks occur which suggest a quality associated with those categories, in most cases the effect of extraneous variables is clearly seen.

TABLE 7 CORRELATION MATRIX FOR THE DETERMINATION TEST

	Mean	Sigma	Correlations: Grain	Passband/ Resolution	Resolution	Accuracy	Confidence
Contrast	0.52	0.33	0.11	-0.10	-0.01	0.20	0.24
Grain	0.08	0.04		-0.05	-0.24	-0.18	-0.12
Passband/ Resolution	0.45	0.06			0.29	0.11	0.08
Resolution	10.6	4.1				0.25	0.21
Accuracy	2.2	1.7					0.50
Confidence	53.	22.					
Multiple R						0.36	0.34

4. Discussion of Results

Direct statistical procedures exist for the derivation of a summary measure* from the numbers in Table 7. However, the inadequacy of the photointerpreter sample preclude the derivation of a valid summary measure. A most convincing argument to illustrate this point is revealed in Figure 11, i.e., the accuracy score distributions for constant physical quality. If the distributions for constant quality were sharply peaked, or spread only slightly about scores, then a summary measure could be derived. However, the distribution scores in Figure 11 are clearly not peaked about any scores. Hence, a valid summary measure cannot be derived from these data. Nevertheless, attempts were made to glean as much information as possible from the data.

From the cases where some prediction is possible and from scatterplots of the same data, it appears that contrast becomes important at scene contrasts below approximately 0.4, indicating perhaps a thresholding effect for the targets of military significance. Additional scatterplots were made in an attempt to elicit further results, but no definite conclusions

* This would be in the form of a multiple regression equation consisting of a weighted combination of the physical variables. See Walker, H. M. and Lev, J. Statistical Inference Henry Holt and Co. 1953

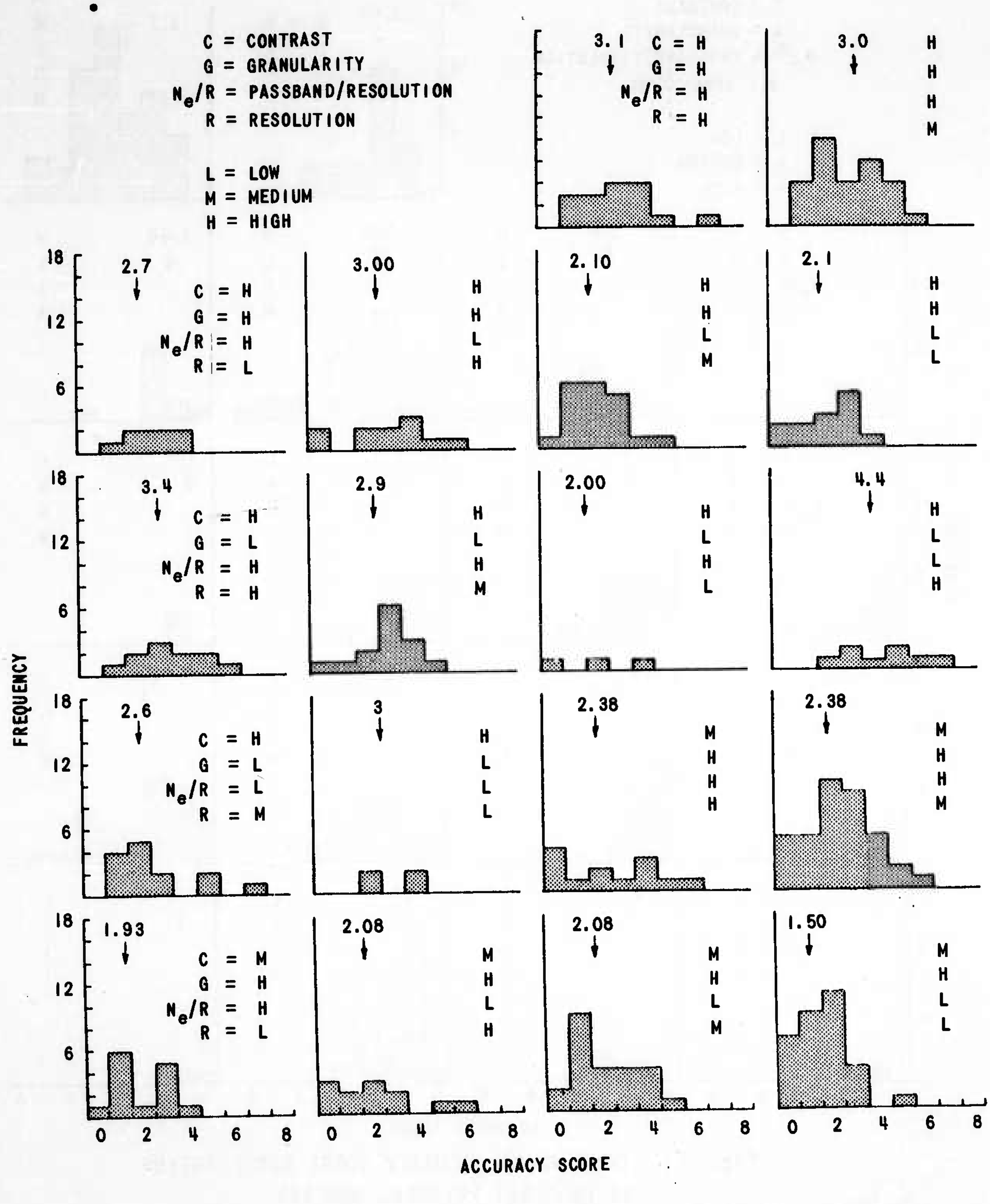

Fig. 11 ACCURACY SCORE DISTRIBUTION FOR CONTRAST PHYSICAL QUALITY

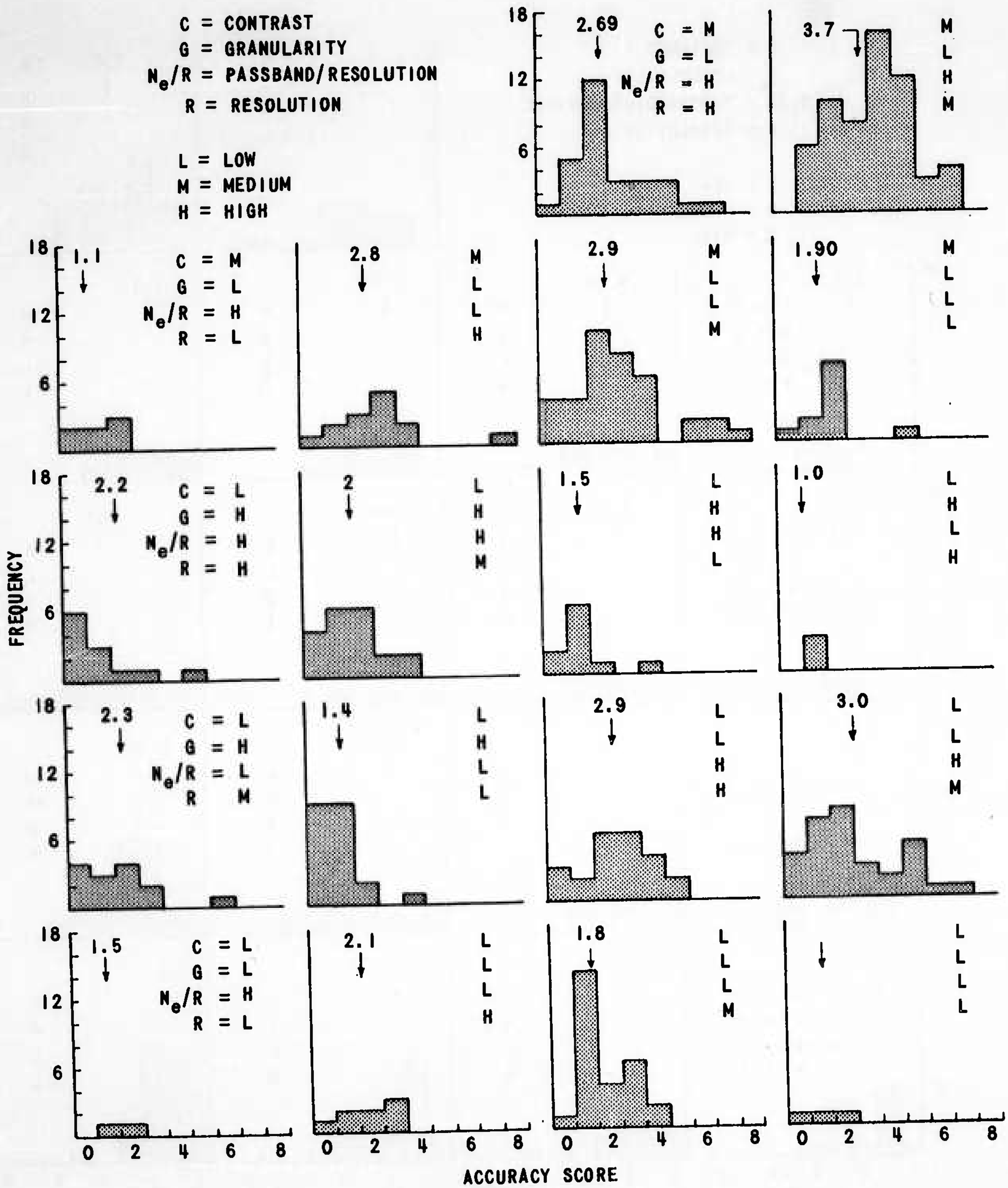

Fig. 11 (CONTINUED) ACCURACY SCORE DISTRIBUTION FOR CONSTANT PHYSICAL QUALITY

could be drawn. However, during the examination of the data the authors formed several opinions which may guide further work. Passband is probably more important than resolution, that is, edge sharpness appears to be of greater importance than separation of fine detail in target identification. Product terms of contrast and grain with resolution (or, more likely, passband) apparently contribute important terms to the summary measure. The product terms are to be expected since the first is essentially a measure of the information available in a given noise term that occurs in Selwyn's equation for resolution.* It must be emphasized, however, that the above predictions are based on weak indications and are therefore conjectures at this time.

Possible reasons for the failure of this test to yield a valid summary measure are:

a) Non-physical variables, e.g., specific scene content may account for some of the variance in performance. This would imply that quantative indices of such variable must be obtained and included in future research programs. The existence of a summary measure for a given scene type and given class of target should definitely be investigated in future programs.

b) The discrepancies between the level of performance required on the test and the level of subject capability may account for some of the variance in performance. Pretesting of the subjects who will perform in a determination test should be able to remedy such a situation. It should be pointed out that if a lack of experience with aerial photographs exists on the part of those subjects being tested, then their results cannot be generalized to obtain meaningful results for the operational case.

Another possibility is that the ranges of physical variables are not representative of those found in operational photointerpretation. Since the correlation coefficients depend on the range of variables, the results are influenced by any shortcomings in the achievement of correct ranges. Although this is true in general, it is felt that this possibility has been ruled out since careful checks indicate that the ranges of variables used in the determination test are representative of those found in operational photointerpretation tasks.

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* Selwyn, E. W. H. The Photographic and Visual Resolving Power of Sensors Photographic Journal Vol. 88B (1948) pp. 46-57

IV. CONCLUSIONS AND RECOMMENDATIONS

It is not possible to derive a summary measure of image quality from the experimental data because of difficulties encountered during the tests. However, a number of valuable conclusions can be drawn and several recommendations made with respect to test procedures, image modification techniques and physical quality measurements.

The primary difficulty encountered during the main test was the difference between the level of capability of the photointerpreters made available and the level of performance required on the test. Hence, in future test programs, effort should be devoted to the design of a test which could be used either as an interpreter selection system or as a control measure of performance.

Although there is insufficient evidence to determine whether the targets and questions selected for the tests would have provided a good range of difficulty for experienced photointerpreters, nevertheless, no process except extensive pretesting exists at present for labeling a given target or question about a target as easy, moderate, or difficult. Such a classification technique should be studied as it would be a valuable aid in selecting photographs and questions for future tests.

A set of 1000 modified photographs with controlled and measured physical parameters is now available. The use of veiling exposures to control contrast and imaging onto various films to control granulatity are good modification techniques. Spatial filtering provides a straightforward control method for modifying the transfer function. Contact printing from modified images created significant changes in the granularity spectrum. As this change has an unknown effect on the interpreter performance, the modified images should be used only as originals until further study of the copying effects are conducted.

Techniques were developed for extracting quality parameters from an aerial scene without recourse to test charts. The measure of scene contrast which was defined is relatively easy to extract and correlates with the visual impression of scene contrast. The values of granularity measured differ from those reported by Kodak, but are in closer agreement with other measurements made by RCA. Further study of the slightly different techniques used in the three cases should resolve this problem.

Although the extraction of the modulation function from an edge scan was successful, several refinements require further study. Among these refinements is the study of smoothing computations to remove noise since no method was found which always provided a satisfactory result. Further, in the case of images in which the pass-band to resolution ratio is small, the edge trace has long tails which make the determination of the total density difference difficult. Finally, when image degradations have occurred during several generations of copying, nonlinear effects are introduced for which no convenient formulation has been generated.

Thus, although a summary measure has not been derived, valuable advances in image quality evaluation have been made in the areas of testing, modifying images and measuring physical parameters.

Appendix I

PHOTOGRAPHIC PARAMETERS

This appendix considers a number of measures which are commonly used to describe a photograph and to relate these measures to the parameters discussed in the main body of the report. Measures considered are coarsely divided into categories of granularity (noise), contrast, resolution, and sharpness.

Granularity

The granularity or noise considered in this report is that which causes density fluctuations in an area in which the image exposure is a constant. The granularity is usually described either by a power density spectrum or simply by a root mean square fluctuation. The calculation of the root mean square fluctuation used in this report is described, and its relation to the power density spectrum is shown both in general and for a special case of interest.

The noise (N) can be described in terms of density (D) as:

$$N(x,y) = D(x,y) - \bar{D} \tag{10}$$

where the density is measured by scanning with a microdensitometer, and $\bar{D}$ is the computed average value. The mean square fluctuation is measured by:

$$\sigma^2 = \frac{1}{X}\int_{-X/2}^{X/2} N^2(x,y)\,dx \tag{11}$$

where the average is taken in only one direction since the function is random. X is the length of the scan used to measure N. The same value would be measured if the average is taken over both dimensions as:

$$\sigma^2 = \frac{1}{X^2}\iint_{-X/2}^{+X/2} N^2(X,y)\,dx\,dy \tag{12}$$

Now, by Parseval's theorem,* the integral of the square of a function is just the integral of the power density spectrum over spatial frequencies (ω_x, ω_y) or:

$$\sigma^2 = \frac{1}{2\pi} \iint_{-\infty}^{+\infty} P_n(\omega_x, \omega_y) d\omega_x, d\omega_y \tag{13}$$

where P_n is the measured power density (power/unit spatial frequency). Equation 13 is the general relation of root mean square fluctuation to the power density spectrum. Since the granularity is normally measured by scanning with a circular aperture, the measured power spectrum is the product of the true grain spatial frequency power spectrum and the square of the aperture modulation function. The modulation function (τ) of the aperture (of radius R) is:

$$\tau(\omega) = \frac{2J_1(\omega R)}{\omega R} \tag{14}$$

where J_1 is the first order Bessel Function.

If it is assumed that the spectrum of the grain is actually a constant (K_1) to some cutoff frequency(ω_c) and zero beyond,** then from 13 and 14:

$$\sigma^2 = K_1 \int_0^{\omega_c} \left[\frac{2J_1(\omega R)}{\omega R}\right]^2 \omega d\omega \tag{15}$$

which can be integrated and reduced to:

$$\sigma^2 = \frac{G^2}{A} \left[1 - \left[J_0^2(\omega_c R) + J_1^2(\omega_c R)\right]\right] \tag{16}$$

where $A = \pi R^2$; G^2 is a constant proportional to K_1 and J_0 is the zero order Bessel Function. For the case where the aperture is a reasonable size and

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* Helstrom, C. W. Statistical Theory of Signal Detection Pergammon Press 1960 p. 340

** It is assumed that the sample length X is large compared to $1/\omega_c$

the cutoff frequency is high, Equation 16 reduces to the expression quoted in the body of the report for aperture dependence:

$$\sigma = G \cdot A^{-1/2} \tag{17}$$

The value of σ also depends upon the average density. The relation takes the form:

$$\sigma = K[\bar{D}]^{n} \tag{18}$$

where K is a proportionality constant depending on film type, etc., and n is a number normally in the range from 0.3 to 0.5.

Contrast

The definition of "scene contrast" is considerably more difficult than "target contrast." Although the exact functional form used for target contrast varies from one investigation to another, all definitions are simply related. For a target image of density D_T on a background density D_0, the target contrast is expressed by various investigators as:

a. $D_0 - D_T$

b. Antilog $(D_0 - D_T)$

c. $[\text{Antilog}\,(D_0 - D_T)] - 1$

d. $\{[\text{Antilog}\,(D_0 - D_T)] - 1\} / \{[\text{Antilog}\,(D_0 - D_T)] + 1\}$.

The extension of these definitions to a scene contrast definition is not obvious. One possibility is to simply consider the target and background densities to become the maximum and minimum density values in the over-all image. Carman and Brown* suggest a range including less than 100% of the observed points, such as 99%, since a specular reflection from the sun might provide a

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* Carman & Brown Brightness of Fine Detail in Ground Photography JOSA 49 p. 629 June 1959

single excessively bright point. Other work, by Carmen and Carruthers* has provided frequency distributions of occurrence of various brightness differences of nearby points in aerial scenes. Such a concept could lead to a functional description of contrast, from which several parameters might be extracted.

Since a single number, rather than a function, was desired as a measure of contrast, the frequency distribution concept was not used in this program. However, the occurrence of density differences in nearby points appears to be a logical extension of the concept of target contrast. Thus, the definition of scene contrast used in this report incorporated the concept of nearby points. To avoid the measurement of a frequency distribution, simply the largest monotonic density changes in a scan were measured, and the six largest were averaged to avoid single specular reflections, as noted above.

Resolution

The word "resolution" is probably the most used, and most misused, word related to image quality. Loosely, resolution measures the ability to reproduce fine detail. To become any more quantitative, the target used and the criterion for resolution must both be defined with reasonable care. Laxity in these definitions causes confusion.

Resolution targets fall generally into the class of repetitive patterns of light and dark bars or pairs of points. The repetitive bars can have various length-to-width ratios, sine or square wave intensity patterns and various contrasts. The pairs of points are usually considered as infinite contrast (i.e., white points on a perfectly black background). The resolution criterion is either a visual limit or some definite density variation when the pattern is scanned by a given midrodensitometer aperture.

Visual resolution tends to mix the effects of modulation function and granularity. For the case of sine wave targets and visual resolution limit, it is possible** to relate the target contrast (C), the system modulation transfer

* Carman & Carruthers Brightness of Fine Detail in Air Photography JOSA 41 p. 305 March 1951

** Selwyn, E. W. H. The Photographic and Visual Resolving Power of Sensors Photographic Journal Vol. 88B (1948) pp. 46-57 function (τ), and the granularity (G) to predict resolution. The resolution limit (R) is predicted as:

$$\gamma C \tau(R) = KGR \tag{19}$$

where γ is the slope of the film H-D curve. C is the target contrast defined as the ratio of peak brightness to average brightness minus one. G is the constant given by Equation 17. . The constant K is essentially the minimum detectable signal-to-noise ratio and is approximately equal to 6. The equation applies, with less precision, to square wave bar charts.

Equation 19 describes the noise-limited case. When the value of the right hand side becomes small, the contrast threshold of the eye becomes significant and Equation 19 ceases to be valid. Although the transition region is in doubt, when the grain is small enough that the contrast threshold of the eye becomes the limiting factor, the resolution can be predicted by:

$$\gamma C \tau(R) = 0.04 \tag{20}$$

A special case of this equation was used in the body of the report as the measure of resolution. For a unit gamma copy of a test chart whose brightness ratio is 1.4:1, then $\gamma = 1$, $C = (1.4-1.2)/1.2 = 1/6$, and Equation 20 reduces to $\tau(R) = 0.24$. Thus, the 25% point of the modulation function is a measure of visual resolution for the case of a sine wave test chart (and approximately for a bar chart) with a brightness ratio of 1.4:1 copied on a nearly grainless film. Obviously, this particular case is only one of the many possible selections of target contrast, each of which would correspond to picking a different point along the modulation transfer curve.

Sharpness

Under the category of sharpness are included those parameters which relate only to the modulation function and possibly to nonlinearities in the system. Thus, these measures are independent of contrast and granularity.

In the sense of arbitrarily choosing a point on the modulation transfer function, the contrast limited resolutions just considered could be grouped with the sharpness definitions.

A measure of sharpness suggested in 1902 is called the "Strehl Intensity" or the "Strehl Definition". Assume the system point spread is described by the intensity distribution $P(x,y)$. The Strehl Intensity is then defined as the maximum of $P(x,y)$, normalized by dividing by the maximum $P(x,y)$ would obtain in a diffraction limited system. While this normalization aids in measuring the effect of lens aberrations, simple normalization to unit energy* would also provide a sharpness measure.

Closely related to the Strehl Intensity is the concept of maximum edge gradient. If the density trace across an edge has been converted to exposure by use of the Density-log Exposure curve, then the edge gradient is related to the line spread function (L) by:**

$$K L(x) = \frac{dH(x)}{dx} \tag{21}$$

where K is a normalization constant which depends on the size of the original step (K = 1 for a unit step), and $H(x)$ is the edge intensity function. Thus, the maximum edge gradient normalized to a unit step is identically the maximum of the line spread and is therefore a one-dimensional equivalent of the Strehl Intensity. It should be noted that on occasion the unnormalized edge gradient is used as a measure of sharpness, but clearly such a function is not unique for a complete scene. For the case of relatively low contrast edges in the original scene, the equation relating the line spread (L) to the density trace (D) across an edge is derived in Appendix II and is:

$$L(x) = \frac{D'(x)\, 10^{\frac{D(x)}{\gamma}}}{\gamma(\log_{10} e)\,(10^{D_1/\gamma} - 10^{D_0/\gamma})} \tag{22}$$

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* i.e., $\iint P(x,y)\,dx\,dy = 1$

** This relation is derived in Appendix II and can be expanded conveniently as:

$$L(x) = \frac{D'(x)}{\gamma_N}\left\{\frac{\left[1+\frac{D(x)-D_0}{\gamma_N}+\frac{1}{2}\left(\frac{D(x)-D_0}{\gamma_N}\right)^2+\cdots\right]}{\left[\frac{D_1-D_0}{\gamma_N}+\frac{1}{2}\left(\frac{D_1-D_0}{\gamma_N}\right)^2+\cdots\right]}\right\} \tag{23}$$

where D_1 and D_0 are the density values far from the edge and $\gamma_N = \gamma(\log e) \cong 0.434\gamma$. If the edge was a low contrast in the original scene, then $(D_1 - D_0)/\gamma_n$ is small compared to unity and Equation 23 can be approximated as:

$$L(x) = \frac{D'(x)}{\Delta D} \tag{24}$$

where $\Delta D = D_1 - D_0$. In that case, the maximum density gradient normalized to a unit density difference is the maximum of the line spread.

Another class of sharpness measures which is related to the above is the measurement of an average density gradient over some percentage of the total density difference across the edge. Frequently, the inverse of this measure is labeled as "edge width." These measures are convenient because such a quantity can be calculated by determining the value of ΔD, the total density change, and then locating the points where the density trace reaches stated percentages of the total. When the percentages are close together near the center of the curve, the inverse of the edge width so defined is directly proportional to the maximum density gradient. Although a correlation will still be evident, choosing points further from the center of the curve will allow varying line spread shapes to create a range of values for the ratio of the maximum density gradient to the reciprocal edge width.

Workers at Kodak * have found that a measure of mean square density gradient tends to correlate with the visual impression of sharpness. This measure, called "acutance", is defined as:

$$A = \frac{\int_{X_1}^{X_2} [D'(x)]^2 dx}{(X_2 - X_1)(\Delta D)} \tag{25}$$

* Perrin, F. H. JSMPTE Vol. 29 p. 151 1960

Where the symbols are the same as in previous equations and X_1 and X_2 are the "ends" of the edge. While the exact definition of X_1 and X_2 is somewhat arbitrary, the frequently used value is that where the density gradient is 0.005 density units/micron.

It is interesting to note the relation between the acutance, defined by Equation 25 and Schade's equivalent passband, used as the sharpness parameter in this report. The passband (N_e) as shown in Appendix II can be computed from:

$$N_e = \frac{1}{2}\int_{-\infty}^{+\infty} L^2(x)\,dx \tag{26}$$

For the same approximations as used in Equation 23 this equation reduces to:

$$N_e = \frac{\int_{-\infty}^{+\infty} [D'(x)]^2 dx}{2(\Delta D)^2} \tag{27}$$

The integrals in Equations 25 and 27 are essentially equal, since $D'(x)$ is negligible beyond the range of X_1 to X_2 . Therefore,

$$A = 2(\Delta D) N_e (X_2 - X_1)^{-1} \tag{28}$$

Since: (1) the X_1 and X_2 values are the points where $|D'(x)| = 0.005$, (2) $L(x)$ is given approximately by Equation 24 and (3) $L(x)$ is constant for all edges in a given area of a scene; then for edges of differing ΔD , (1) N_e is a constant and (2) A increases with ΔD for any line spread shape in which the tail of $L(x)$ decreases faster than (K/x).

In order to illustrate the various sharpness measurements and to indicate possible sources of error, two numerical examples are presented below. These are an exponential and a Gaussian modulation function:

$$\tau_1(\nu) = e^{-.05|\nu|} \qquad \tau_2(\nu) = e^{-.0018\nu^2} \tag{29}$$

where ν is measured in lines/millimeter. The curves are plotted in Figure 12 and it can be seen that both curves cross 0.25 at ν = 27.8 lines/mm millimeter. The corresponding line spread functions can be calculated to be:

$$L_1(x) = \frac{40}{(1 + .0158x^2)} \qquad L_2(x) = 41.8\, e^{-.00548x^2} \tag{30}$$

where x is measured in microns. These curves are plotted in Figure 13.

A particular case was assumed, namely an original edge in which the exposure changes by a factor of 2, copied by systems with each of the above line spreads onto a film developed to a gamma of 2. The density traces are shown in Figure 14. Table 8 summarizes the various sharpness measures: the resolution, R, (25% point of τ), the passband, N_e, their ratio, the value of the maximum of the line spread, $L(x)_{MAX}$ the normalized maximum density gradient, $[D'(x)/\Delta D]$ maximum, the reciprocal edge width, $(T_{10})^{-1}$, between the 10% and 90% points in density, and the acutance, A. The two measures which depend on (ΔD) are also given (and subscripted PRAC) where (ΔD) has been taken as the density difference between the endpoints shown in Figure 14 rather than the theoretical limits. Obviously, similar errors would be contained in the determination of $L(x)$, and therefore, in N_e and R, if the procedure outlined in Appendix II was used to determine $L(x)$ from $D(x)$.

What is perhaps of greatest interest in Table 8 is the good correlation between the maximum value of the line spread and the resolution (25% point). This constant ratio, also observed in the values measured on imagery, is about 1.45. For cases where the normalized density gradient is a good approximation to $L(x)$, this provides a quick approximation to R. The reciprocal edge width tends to vary in the manner of passband or acutance, although the measurement becomes sensitive to the choice of ΔD in the curve which has a low passband to resolution ratio.

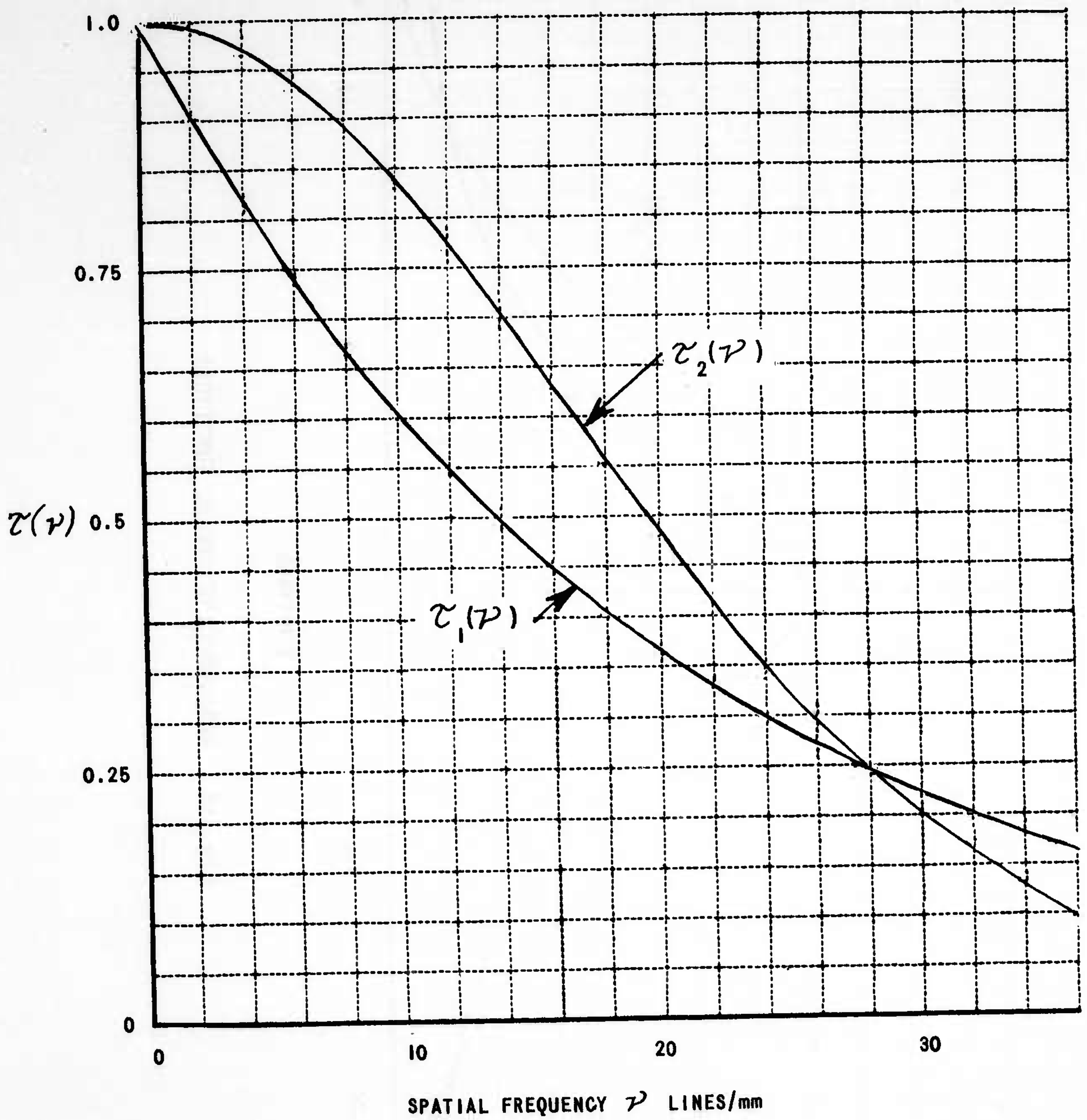

Fig. 12 SAMPLE TRANSFER CURVES

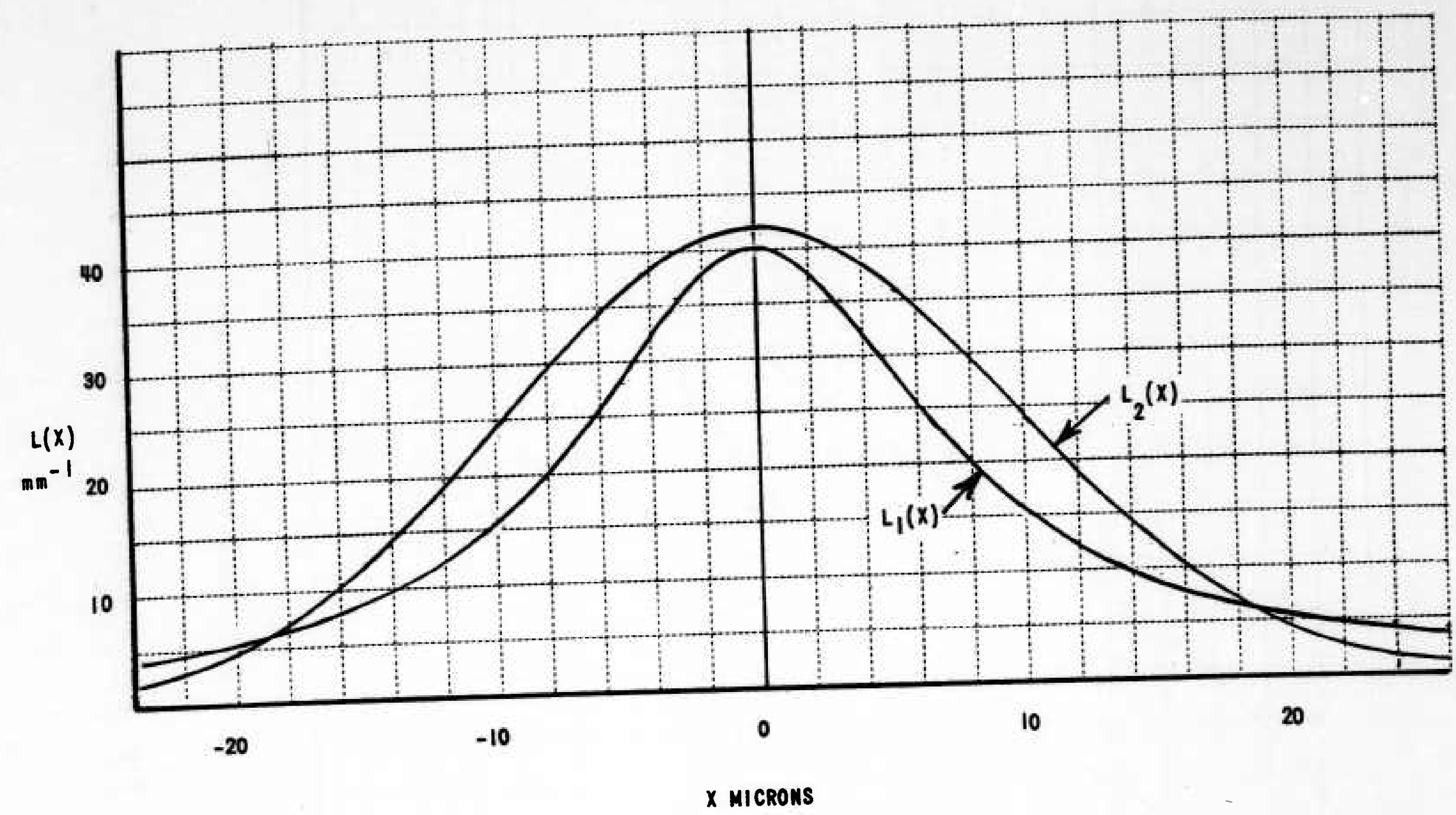

Fig. 13 DERIVED LINE SPREAD FUNCTIONS

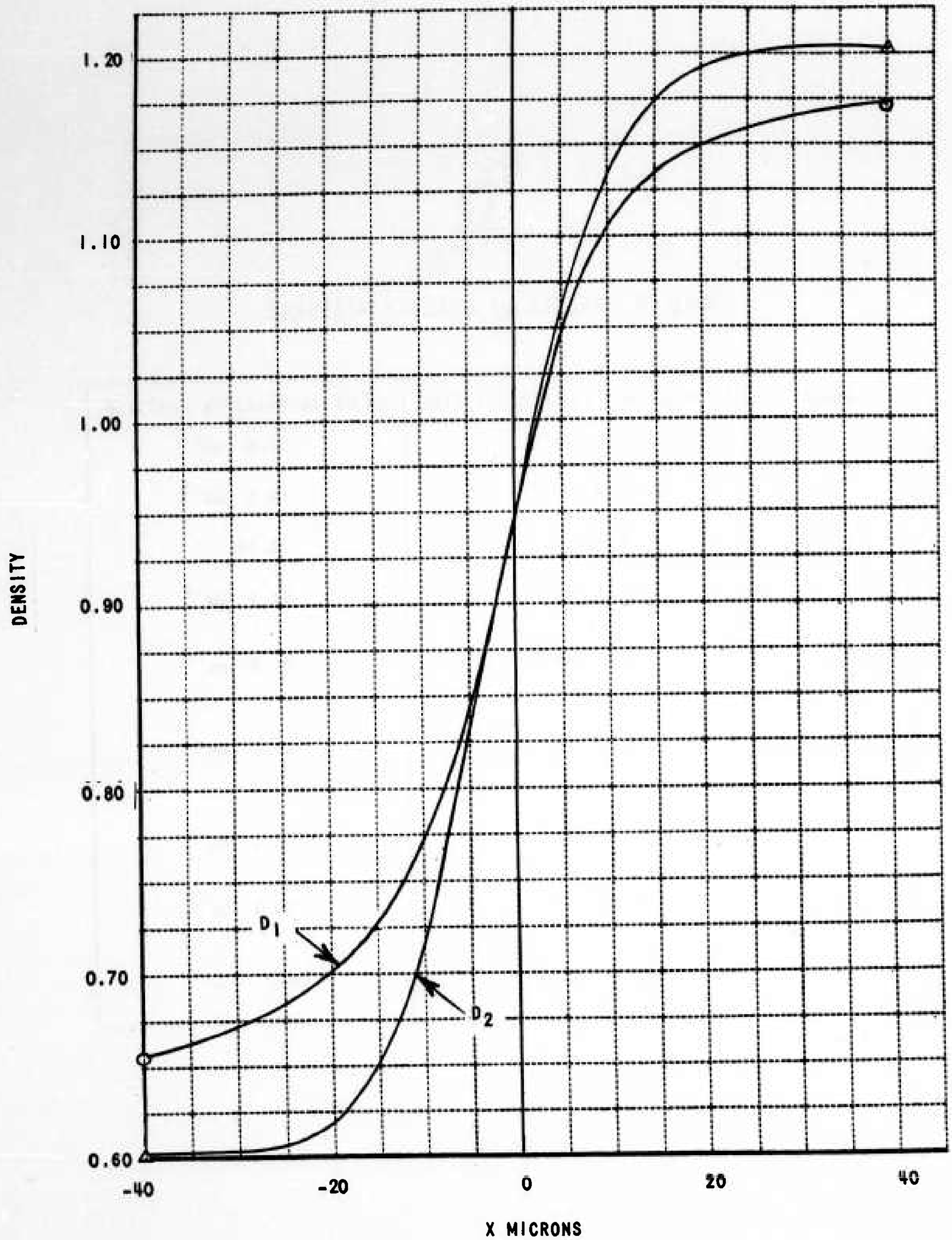

Fig. 14 DERIVED DENSITY TRACES

TABLE 8 VALUES OF QUALITY MEASURES

MEASURE	EXPONENTIAL TRANSFER FUNCTION	GAUSSIAN TRANSFER FUNCTION
R	27.8 mm^{-1}	27.8 mm^{-1}
N_e	10.0 mm^{-1}	14.8 mm^{-1}
N_e/R	0.36	0.53
$\left[L(x)\right]_{max}$	40.0 mm^{-1}	41.8 mm^{-1}
$\left[\frac{D'(x)}{\Delta D}\right]_{max}$	39.0 mm^{-1}	41.5 mm^{-1}
$\left[\frac{D'(x)}{\Delta D}\right]_{max,prac.}$	45.3 mm^{-1}	41.5 mm^{-1}
T_{10}^{-1}	18.9 mm^{-1}	40.0 mm^{-1}
$\left[T_{10}^{-1}\right]_{prac.}$	31.3 mm^{-1}	40.0 mm^{-1}
A	352. mm^{-2}	490. mm^{-2}

Appendix II

DETERMINATION OF RESOLUTION AND EQUIVALENT PASSBAND

It is the purpose of this appendix to show how the resolution, and the ratio of passband to resolution occur in the mathematical description of an image on a photographic transparency, and how they are extracted from the density trace across an edge.

The basis of the imaging process is the image of a point. In a linear process, the exposure $E(x,y)$ of a transparency can be related to any object function $B(x,y)$ by superimposing the images of the individual object points:

$$E(x,y) = \iint_{-\infty}^{+\infty} B(x',y')\, P(x-x', y-y')\, dx'\, dy' \qquad (31)$$

where $P(x,y)$ is the "point spread" function and is assumed to be real. The Fourier transform of the point spread function is called the "two-dimensional optical transfer function." The one-dimensional case is of primary interest here and therefore with $B = B(x)$ Equation 31 becomes:

$$E(x) = \int_{-\infty}^{\infty} B(x') \left[\int_{-\infty}^{\infty} P(x-x', y-y')\, dy' \right] dx' \qquad (32)$$

The "line spread function," $L(x)$ is defined as the cross section of the image of a line object, and so with $B(x) = \delta(x)$ the line spread is:

$$L(x) = \int_{-\infty}^{\infty} P(x,y)\, dy \qquad (33)$$

and Equation 32 is now written:

$$E(x) = \int_{-\infty}^{\infty} B(x')\, L(x-x')\, dx' \qquad (34)$$

The Fourier transform of $L(x)$ is the "one-dimensional optical transfer-function,"

$$\tau(\omega) = \int_{-\infty}^{\infty} L(x)\, e^{i\omega x}\, dx \tag{35}$$

Two comments are in order regarding the above integrals. First, normalization constants have been ignored, but the common definitions of $L(x)$ and $\tau(\omega)$ are such that:

$$\tau(0) = \int_{-\infty}^{\infty} L(x)\, dx = 1 \tag{36}$$

Second, it should be noticed that in the general case $P(x,y)$ is not rotationally symmetric, and therefore the line spread depends upon the orientation of the line. However, only symmetric point spreads are of concern in this study and therefore either $L(x)$ or $\tau(\omega)$ is sufficient to determine uniquely the image of a given object function.

Of the four parameters selected to describe image quality, resolution and equivalent passband are determined from the modulation curve. Since $\tau(\omega)$ is complex in general, it can be expressed as:

$$\tau(\omega) = \tau_0(\omega)\, e^{i\phi(\omega)} \tag{37}$$

where $\tau_0(\omega)$ is a real, positive function called the "modulation transfer function." For the purpose of this study, "resolution," R, is defined as the lowest frequency for which τ_0 is equal to 0.25. The equivalent passband, N_e, has been defined by Schade:*

$$N_e = \int_0^{\infty} \tau_0^2(v)\, dv \qquad \left(v = \frac{\omega}{2\pi}\right) \tag{38}$$

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* Schade, O. H. A New System of Measuring and Specifying Image Definition National Bureau of Standards, Circular 526 April 29, 1954

It is quickly seen from the above equations that passband and resolution can be determined if the exposure $E(x,y)$ (or equivalently the density) is measured in the image for a known object function $B(x,y)$. Since the object is not available, a knowledge of $B(x,y)$ must be obtained by interpretation. The most frequently occurring object function which can easily be recognized in the image is a sharp transition (i.e., an edge). The mathematical expression of a sharp edge may be written:

$$B(x) = \begin{cases} \alpha_1 & (x < 0) \\ \alpha_2 & (x > 0) \end{cases} \tag{39}$$

where α_1 and α_2 are unknown constants. Using this object function in Equation 34, the image function $E(x)$ becomes:

$$E(x) = \alpha_1 \int_{-\infty}^{0} L(x-x')\, dx' + \alpha_2 \int_{0}^{\infty} L(x-x')\, dx' \tag{40}$$

which, by a change of variables $\xi = (x - x')$ and the use of the condition of Equation 36, can be written:

$$E(x) = (\alpha_2 - \alpha_1) \int_{-\infty}^{x} L(\xi)\, d\xi + \alpha_1 \tag{41}$$

Differentiating Equation 41, the line spread function can be written:

$$L(x) = \frac{E'(x)}{\alpha_2 - \alpha_1} \tag{42}$$

In order to relate $L(x)$ to the densitometer trace of an edge on a photographic transparency, a digression is necessary to discuss the terms and properties of film transparencies. After the exposed film is developed, the film image is expressed by either the "transmission" (T) which is the ratio of transmitted to incident light intensity, or "density" (D) which is:

$$D = \log_{10} \frac{1}{T} \tag{43}$$

The empirical relation between the film density and the exposure is given by the Hurter-Duffield curve. Figure 15 is a schematic representation of a typical H-D curve for a photographic emulsion. Exposures are assumed to lie within the linear portion of the curve. The slope of the linear part is the film "gamma" (γ) and its value depends upon how the film was developed. Therefore, the relation between D and E within the useful exposure range is:

$$D = \gamma \log E + k \tag{44}$$

It is density that is to be related to the line spread function since this is the quantity recorded in the scanning process. Eliminating the exposure function between Equations 42 and 44, $L(x)$ can be written:

$$L(x) = \frac{D'(X)\ 10^{\frac{D(x)-k}{\gamma}}}{\gamma(\alpha_2 - \alpha_1)\ \log_{10} e} \tag{45}$$

Assuming $L(x)$ approaches 0 when $X \rightarrow \pm\infty$, limiting densities can be defined:

$$D(x) \longrightarrow \begin{cases} D_0\ (X \rightarrow -\infty) \\ D_1\ (X \rightarrow \infty) \end{cases} \tag{46}$$

Incorporating these definitions, and again using the normalization condition on $L(x)$(Equation 36 Equation 45 can be written:

$$L(x) = \frac{D'(x)\ 10^{\frac{D(x)-D_0}{\gamma}}}{\gamma(\log_{10} e)\left(10^{\frac{D_1 - D_0}{\gamma}} - 1\right)} \tag{47}$$

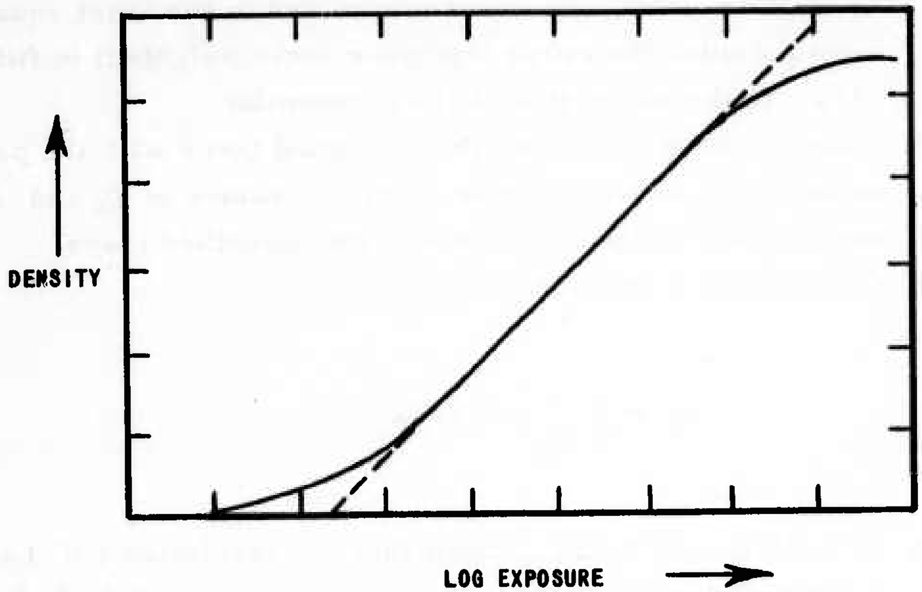

Fig. 15 TYPICAL HURTER AND DRIFFIELD CURVE

Using Equation 47, the calculation of resolution and equivalent passband was carried out by an IBM 704 computer in the following manner.

1. Sampling of density trace of edge (microdensitometer output)
2. Smoothing to eliminate fluctuations due to grain noise. Presently, smoothing is done by a least squares fit of a 7th degree polynomial to the sampled density trace. The 7th degree was selected as a compromise between poor fitting of lesser degree polynomials, and the tendency of higher degree polynomials to follow grain noise. Since $L(x)$ depends explicitly on $D'(x)$ as well as $D(x)$, the error minimized in the least squares process includes the error (approximately weighted) in fitting $D'(x)$ to the derivative of the polynomial.
3. Calculation of $L(x)$ using the smoothed trace with the proper value of γ assumed known, and the values of D_0 and D_1 determined by the end points at the smoothed trace.
4. Calculation of equivalent passband*

$$N_e = \frac{1}{2}\int_{-\infty}^{\infty} L^2(x)\,dx \qquad (48)$$

5. Calculation of $\tau_0(\omega)$, from this the resolution (R) is determined as the lowest frequency at which $\tau_0(\omega/2\pi)$ becomes 0.25.

The discussion up to this point has considered an image that results from only one degrading process; that is, the image transparency is a first generation photograph. Some comments are in order regarding an image resulting from two or more steps, each of which may or may not degrade the image. Consider a two-step process where the original scene is imaged onto a negative transparency and then copies onto a second negative transparency. Three cases are possible:

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* Agreement with Equation 38 can be shown by Parseval's theorm. Helstrom, C. W. Statistical Theory of Signal Detection Pergammon Press p. 340 1960

1. The primary degradation occurs only in the second step
2. The primary degradation occurs only in the first step
3. Both steps contribute significantly to the net degradation

In the first case, no problems arise and the preceding mathematics are applicable when it is understood that the proper value of γ is just that of the second transparency. The mathematics still hold for the second case, if the value of γ is:

$$\gamma = -\gamma_1 \gamma_2 \tag{49}$$

where γ_1 and γ_2 are the values for the first and second transparencies. In the last cases where both steps degrade but neither is dominant, a simple convolution integral (Equation 31) usually cannot be written and therefore there is in general no point spread function that will describe the two-step process. The calculation of $L(x)$, for example, will yield a function that would depend upon which edge in the format was scanned. There are special cases, however, for which line spread functions do exist and two of these are:

1. Low contrast object scene
2. $\gamma_1 = \gamma_2 = 1$

For each of the above cases, the effective line spread function $[L_e(x)]$ is the convolution of the line spread functions for each step:

$$L_e(x) = \int_{-\infty}^{\infty} L_1(x') L_2(x - x') \, dx' \tag{50}$$

Appendix III

SPATIAL FILTERING

A two-dimensional pattern, such as a photograph, consisted of a surface distribution of light and dark areas which can be expressed as a two-dimensional function $f(x,y)$ of coordinates on the surface. The breakdown of $f(x,y)$ into its spatial frequency distribution is given by its two-dimensional Fourier transform:

$$g(\omega_x, \omega_y) = \iint_{-\infty}^{+\infty} f(x,y)\, e^{-i(\omega_x x + \omega_y y)}\, dx\, dy \qquad (51)$$

The parameters ω_x and ω_y (or to be precise: $\frac{\omega_x}{2\pi}$ and $\frac{\omega_y}{2\pi}$ are the frequencies in the x and y directions and have units of cycles per unit distance as measured in the plane of $f(x,y)$. The transform function is just a measure of the contribution of each of the frequencies, corresponding to a particular phase and orientation, to the pattern $f(x,y)$. In general, both $f(x,y)$ and $g(\omega_x, \omega_y)$ are complex and it will be convenient to refer to their intensities. The intensity of a function $f(x,y)$ is the square of its absolute value $|f(x,y)|^2$. The intensity of the complex spectral amplitude $|g(\omega_x, \omega_y)|^2$ is referred to as the power spectrum.

Optical Technique

The basis for being able to carry out this transform optically, is that under certain conditions the diffraction pattern of a two-dimensional object is itself the two-dimensional Fourier transform of the object. The procedure of spatial filtering is to generate optically the Fourier transform of a picture by means of diffraction, modify the frequency spectrum, by appropriate filtering, and then obtain an altered image of the original object. A system for performing these operations is shown in Figure 16 and consists of a monochromatic point source illuminating a film transparency

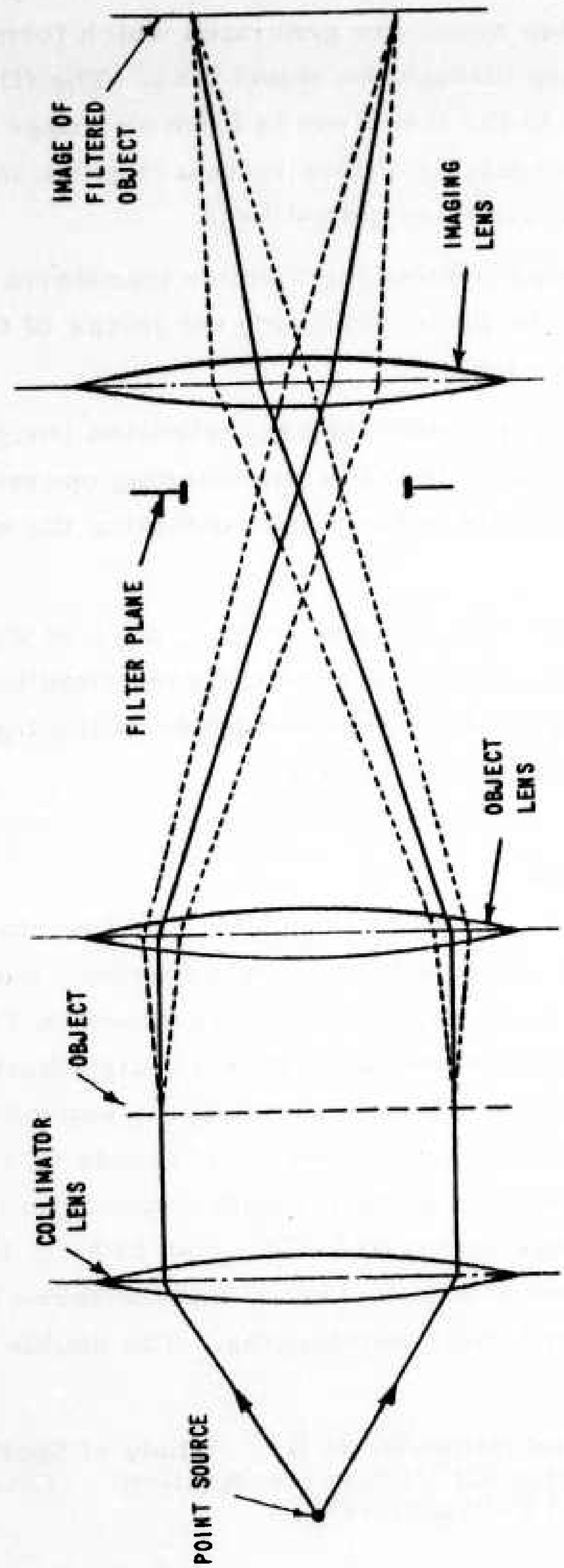


Fig. 16 THREE LENS SPATIAL FILTERING SYSTEM

(object) which is the picture to be analyzed. As the wave passes through the transparency, diffraction waves are generated which form a pattern in the filter plane after passing through the object lens. The filtered diffraction waves then recombine in the last plane to form an image of the original transparency. A complete analysis of this system is given in a previous report,* and some of the results are quoted here.

1. The plane representing the Fourier transform of the object function, is the plane containing the image of the point source formed by the lens.

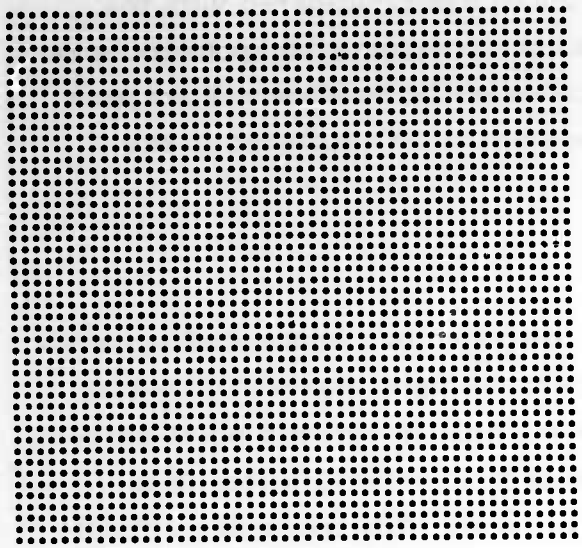
2. The plane representing the reconstructed image of the object is not shifted as a result of the filtering operation and hence remains conjugate to the plane containing the object transparency.

3. The functions $f(x, y)$ and $g(\omega_x, \omega_y)$ of Equation 51 within a phase factor, are the complex amplitude functions representing the amplitude and phase of the light in the object and filter planes respectively.

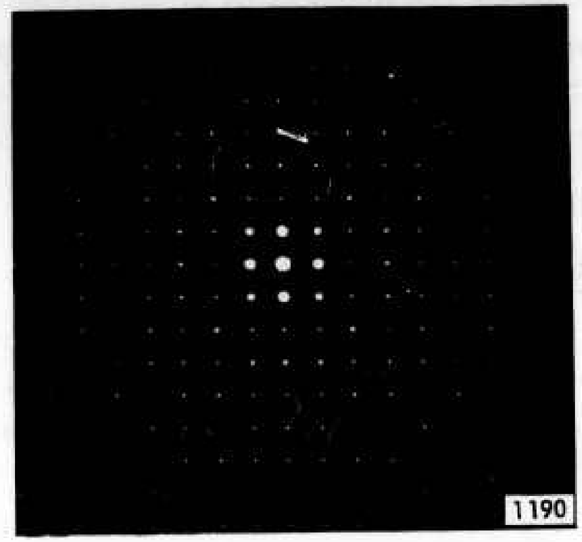
Example of Spectral Analysis

As a demonstration of how the frequency components of an object are distributed in the filter plane, a halftone transparency and its spatial frequency spectrum are given in Figure 17 . As shown in Figure 17 the halftone is periodic and therefore has a spectral distribution that is discrete rather than continuous. This is shown in the second photograph (Figure 17b), where the bright central spot corresponds to zero frequency. The orientation of the components of the frequency spectrum of the halftone can be understood by considering Figures 17c and 17d . Figure 17c is a schematic of the halftone of Figure 17a , and the three lowest periodicities are indicated along with their wavelengths. The double headed arrows

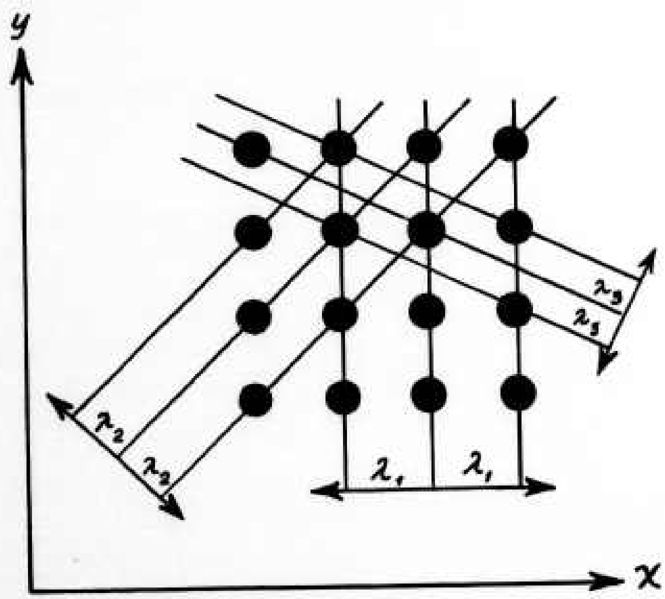
* Roetling, P.G., and Hammill, H.B. Study of Spatial Filtering by Optical Diffraction for Pattern Recognition CAL Report No. VE-1522-G-1 13 February 1962



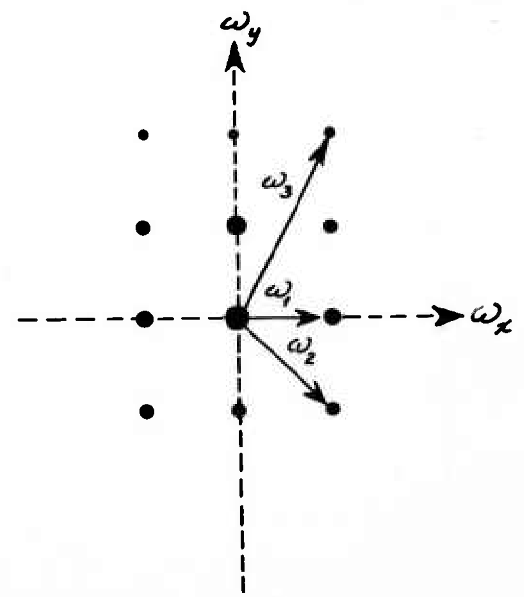
(a) MAGNIFIED HALFTONE



(b) HALFTONE POWER SPECTRUM



(c) HALFTONE SHOWING PERIODICITIES

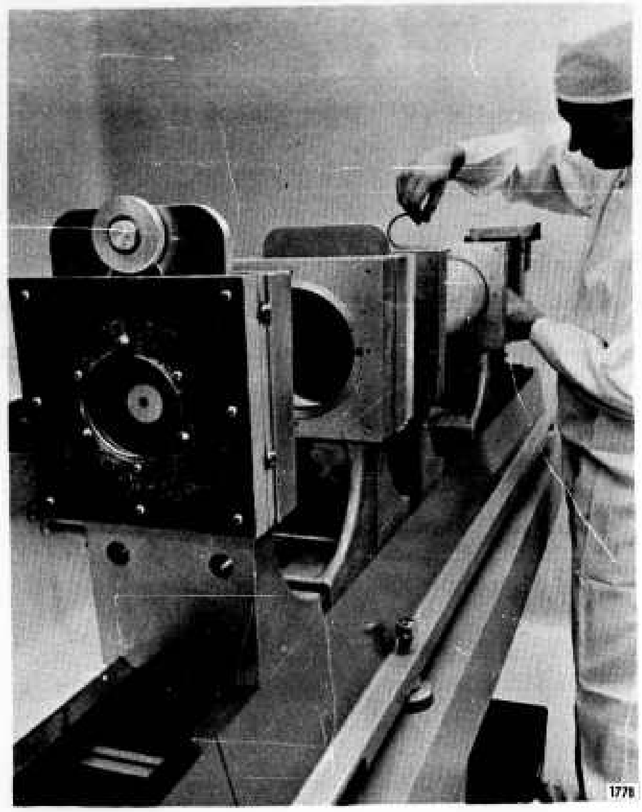


(d) POWER SPECTRUM SHOWING ORIENTATION OF FREQUENCY COMPONENTS

Fig. 17 ANALYSIS OF HALFTONE-TRANSPARENCY indicate the orientation of the periodicity, and when compared with the spectrum of Figure 17d , it is seen that the frequency components have the same orientation. Since the periodicities of the halftone are not sine waves, harmonic frequencies of each fundamental are included in the spectrum.

Spatial Filtering Apparatus

The spatial filtering equipment, installed in a controlled environment laboratory (Figure 18.) uses a mercury light source filtered to pass the 4360 Å line which illuminates a pin hole to obtain a point source. The collimator and objective lenses, both of 5'' aperture, allow up to approximately 3'' x 3'' transparencies to be used. The frequency cut-off of the system is about 100 lines/mm. Both the image transparency and spatial filter are normally immersed in liquid gates in order to eliminate phase effects due to optical path differences through the film, and the holder for the filter is rotatable.



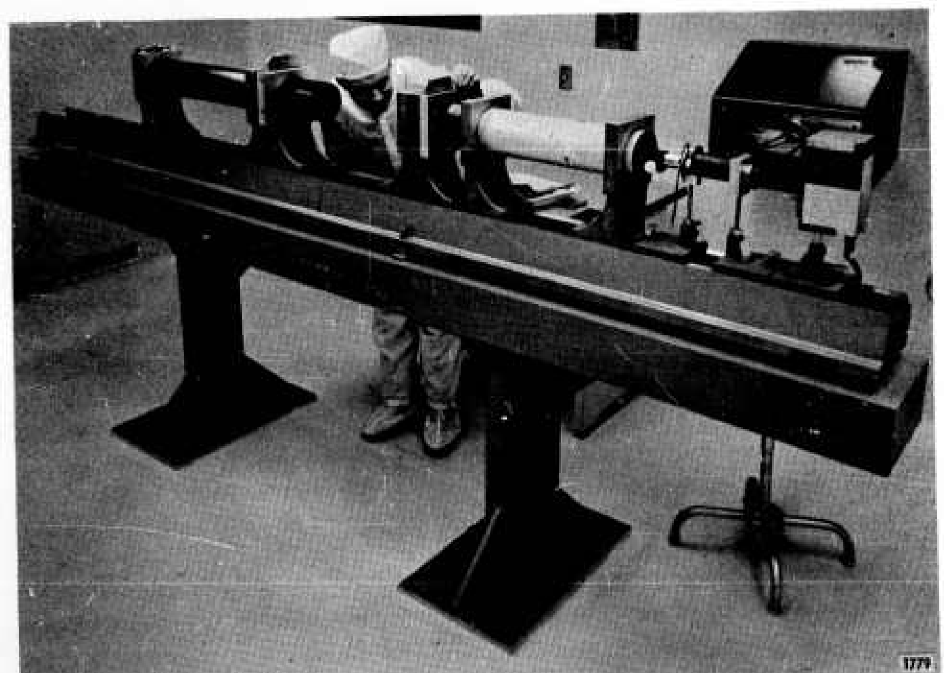


Fig. 18 SPATIAL FILTERING EQUIPMENT

Appendix IV PRETEST DATA

This appendix is a tabulation of the data pertinent to the pretest, giving (1) the values of the quality parameters for each scene, (2) the task in which the scene was used and (3) the interpreters scores for accuracy and confidence in identifying the objects.

TABLE 9

PRETEST DATA

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm-1)	NUMBER RIGHT	MEAN CONFIDENCE (in %)	TASK	P.I.	ORDER NO.	SCENE NO.
0.16	0.019	0.52	07.3	2	39	1	1	1	5331
0.23	0.039	0.80	17.0	2	29	1	1	2	4784
0.08	0.031	0.57	11.0	3	43	1	1	3	4914
0.43	0.031	0.53	04.5	2	32	1	1	4	4861
0.20	0.030	0.80	11.0	4	43	1	1	5	5394
0.28	0.051	0.51	06.4	1	26	1	1	6	4492
0.29	0.022	0.50	13.0	7	45	1	1	7	4463
0.77	0.037	0.61	07.8	5	59	1	1	8	5386
0.65	0.029	0.50	06.7	6	42	1	1	9	4888
0.55	0.090	0.54	03.5	3	25	1	1	10	4750
0.36	0.042	0.61	09.2	5	38	1	2	1	4784
0.35	0.026	0.52	11.0	4	28	1	2	2	5394
0.18	0.036	0.56	11.0	8	18	1	2	3	4463
0.33	0.034	0.62	11.0	5	28	1	2	4	4914
0.65	0.044	0.45	06.2	9	75	1	2	5	4888
0.14	0.067	0.52	13.0	3	10	1	2	6	4492
0.35	0.062	0.80	13.0	7	46	1	2	7	5331
0.72	0.053	0.55	05.4	8	44	1	2	8	4861
0.44	0.069	0.60	09.7	10	88	1	2	9	5386
0.19	0.034	0.80	07.8	5	28	1	2	10	4750
0.06	0.016	0.76	14.0	2	00	1	3	1	4492
0.41	0.034	0.74	10.0	7	30	1	3	2	4914
0.35	0.050	0.57	19.0	8	40	1	3	3	5386
0.73	0.053	0.50	13.0	3	25	1	3	4	4784
0.21	0.057	0.80	11.0	5	30	1	3	5	5331
0.23	0.038	0.50	06.6	4	12	1	3	6	4888
0.31	0.039	0.61	13.0	4	20	1	3	7	5394
0.41	0.027	0.54	03.5	5	32	1	3	8	4861
0.18	0.054	0.57	03.1	3	12	1	3	9	4750
0.27	0.039	0.47	15.0	5	48	1	3	10	4463
0.38	0.051	0.59	11.0	5	36	1	4	1	5331
0.65	0.055	0.68	15.0	7	25	1	4	2	4750
0.12	0.029	0.64	07.8	3	02	1	4	3	4914
0.58	0.044	0.64	11.0	4	32	1	4	4	4861
0.44	0.059	0.59	06.7	5	18	1	4	5	5386
0.17	0.053	0.57	05.4	1	03	1	4	6	4784
0.25	0.048	0.47	25.0	5	06	1	4	7	5394

TABLE 9 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (In %)	TASK	P.I.	ORDER NO.	SCENE NO.
0.25	0.047	0.66	13.0	6	38	I	4	8	4888
0.35	0.052	0.55	05.0	6	29	I	4	9	4492
0.21	0.035	0.59	22.0	6	58	I	4	10	4463
0.67	0.052	0.50	07.5	6	34	I	5	1	4888
0.49	0.045	0.60	14.0	10	59	I	5	2	5386
0.55	0.034	0.63	14.0	5	48	I	5	3	4914
0.18	0.036	0.50	12.0	1	14	I	5	4	4492
0.20	0.036	0.62	04.6	2	07	I	5	5	4463
0.31	0.056	0.62	05.2	4	15	I	5	6	5394
0.55	0.079	0.64	05.5	3	35	I	5	7	5331
0.31	0.029	0.62	05.1	4	30	I	5	8	4861
0.10	0.065	0.68	05.6	2	16	I	5	9	4784
0.57	0.062	0.51	03.9	5	19	I	5	10	4750
0.20	0.039	0.69	12.0	2	62	I	6	1	4463
0.34	0.051	0.56	06.0	3	56	I	6	2	5331
0.19	0.038	0.61	16.0	3	64	I	6	3	4784
0.34	0.050	0.78	05.7	4	54	I	6	4	4888
0.54	0.054	0.62	18.0	3	68	I	6	5	4861
0.29	0.042	0.44	08.6	1	59	I	6	6	4492
0.41	0.041	0.55	17.0	5	53	I	6	7	5386
0.62	0.050	0.60	06.7	2	71	I	6	8	4750
0.12	0.039	0.53	12.0	3	36	I	6	9	5394
0.17	0.037	0.54	17.0	3	73	I	6	10	4914
0.11	0.040	0.51	09.2	0	56	I	7	1	4784
0.17	0.051	0.58	11.0	6	57	I	7	2	4888
0.40	0.085	0.53	12.0	4	60	I	7	3	5331
0.50	0.042	0.55	22.0	8	64	I	7	4	5394
0.38	0.042	0.63	06.7	5	68	I	7	5	4750
0.61	0.055	0.53	07.2	5	63	I	7	6	5386
0.38	0.064	0.52	07.8	7	48	I	7	7	4463
0.41	0.067	0.60	04.8	3	49	I	7	8	4914
0.48	0.023	0.56	07.3	2	49	I	7	9	4492
0.29	0.038	0.60	04.2	1	46	I	7	10	4861
0.44	0.051	0.62	10.4	7	34	I	8	1	4888
0.21	0.037	0.66	08.9	6	32	I	8	2	5386
0.25	0.032	0.60	11.0	7	48	I	8	3	5331
0.41	0.035	0.62	07.3	2	30	I	8	4	4784
0.64	0.055	0.45	07.0	4	25	I	8	5	4914
0.38	0.035	0.53	14.0	7	60	I	8	6	4463

TABLE 9 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm-l)	NUMBER RIGHT	MEAN CONFIDENCE (in %)	TASK	P.I.	ORDER NO.	SCENE NO.
0.39	0.040	0.48	40.0	2	23	I	8	7	4861
0.55	0.046	0.56	4.7	7	37	I	8	8	5394
0.26	0.035	0.64	10.0	8	84	I	8	9	4750
0.12	0.026	0.60	05.2	3	18	I	8	10	4492
0.44	0.072	0.59	10.0	8	86	I	9	1	4888
0.75	0.031	0.36	06.2	4	74	I	9	2	5394
0.52	0.033	0.55	16.0	8	85	I	9	3	4463
0.45	0.062	0.58	03.9	1	55	I	9	4	4861
0.12	0.035	0.53	06.7	2	77	I	9	5	4784
0.21	0.028	0.62	04.4	6	62	I	9	6	5386
0.22	0.034	0.60	06.2	6	70	I	9	7	4750
0.11	0.031	0.59	04.8	4	67	I	9	8	5331
0.26	0.035	0.59	08.4	3	66	I	9	9	4492
0.21	0.045	0.67	07.2	3	58	I	9	10	4914
0.24	0.038	0.58	05.7	1	31	I	10	1	4492
0.46	0.044	0.67	11.0	4	68	I	10	2	5331
0.52	0.064	0.80	09.5	4	43	I	10	3	4861
0.42	0.049	0.61	12.0	6	50	I	10	4	5386
0.47	0.099	0.66	07.8	4	46	I	10	5	4750
0.32	0.042	0.52	07.3	5	23	I	10	6	4888
0.32	0.053	0.59	07.5	1	17	I	10	7	4784
0.05	0.023	0.59	07.8	5	20	I	10	8	4463
0.17	0.036	0.80	03.0	3	29	I	10	9	4914
0.16	0.033	0.64	08.8	3	20	I	10	10	5394
0.16	0.019	0.52	07.3	4	30	S	1	1	5331
0.23	0.039	0.80	17.0	3	50	S	1	2	4784
0.08	0.031	0.57	11.0	3	23	S	1	3	4914
0.43	0.031	0.53	04.5	1	30	S	1	4	4861
0.20	0.030	0.80	11.0	4	53	S	1	5	5394
0.28	0.051	0.51	06.4	3	44	S	1	6	4492
0.29	0.022	0.50	13.0	3	20	S	1	7	4463
0.77	0.037	0.61	07.8	6	46	S	1	8	5386
0.65	0.029	0.50	06.7	3	22	S	1	9	4888
0.55	0.090	0.54	03.5	2	42	S	1	10	4750
0.36	0.042	0.61	09.2	3	17	S	2	1	4784
0.35	0.026	0.52	11.0	4	24	S	2	2	5394
0.18	0.036	0.56	11.0	4	27	S	2	3	4463
0.33	0.034	0.62	11.0	2	19	S	2	4	4914
0.65	0.044	0.45	06.2	6	43	S	2	5	4888

TABLE 9 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm⁻¹)	NUMBER RIGHT	MEAN CONFIDENCE (in %)	TASK	P.I.	ORDER NO.	SCENE NO.
0.14	0.067	0.52	13.0	1	19	S	2	6	4492
0.35	0.062	0.80	13.0	3	44	S	2	7	5331
0.72	0.053	0.55	05.4	3	18	S	2	8	4861
0.44	0.069	0.60	09.7	5	54	S	2	9	5386
0.19	0.034	0.80	07.8	4	09	S	2	10	4750
0.06	0.016	0.76	14.0	1	11	S	3	1	4492
0.41	0.034	0.74	10.0	6	33	S	3	2	4914
0.35	0.050	0.57	19.0	4	02	S	3	3	5386
0.73	0.053	0.50	13.0	3	20	S	3	4	4784
0.21	0.057	0.80	11.0	3	00	S	3	5	5331
0.23	0.038	0.50	06.6	2	00	S	3	6	4888
0.31	0.039	0.61	13.0	3	08	S	3	7	5394
0.41	0.027	0.54	03.5	4	30	S	3	8	4861
0.18	0.054	0.57	03.1	1	08	S	3	9	4750
0.27	0.039	0.47	15.0	3	14	S	3	10	4463
0.38	0.051	0.59	11.0	4	76	S	4	1	5331
0.65	0.055	0.68	15.0	7	82	S	4	2	4750
0.12	0.029	0.64	07.8	1	25	S	4	3	4914
0.58	0.044	0.64	11.0	5	91	S	4	4	4861
0.44	0.059	0.59	06.7	4	28	S	4	5	5386
0.17	0.053	0.57	05.4	1	60	S	4	6	4784
0.25	0.048	0.47	25.0	2	24	S	4	7	5394
0.25	0.047	0.66	13.0	4	66	S	4	8	4888
0.35	0.052	0.55	05.0	4	56	S	4	9	4492
0.21	0.035	0.59	02.2	6	60	S	4	10	4463
0.67	0.052	0.50	07.5	5	70	S	5	1	4888
0.49	0.045	0.60	14.0	7	82	S	5	2	5386
0.55	0.034	0.63	14.0	5	43	S	5	3	4914
0.18	0.036	0.50	12.0	2	30	S	5	4	4492
0.20	0.036	0.62	04.6	1	18	S	5	5	4463
0.31	0.056	0.62	05.2	2	29	S	5	6	5394
0.55	0.079	0.64	05.5	4	40	S	5	7	5331
0.31	0.029	0.62	05.1	4	34	S	5	8	4861
0.10	0.065	0.68	05.6	2	32	S	5	9	4784
0.57	0.062	0.51	03.9	2	32	S	5	10	4750
0.20	0.039	0.69	12.0	2	18	S	6	1	4463
0.34	0.051	0.56	06.0	4	38	S	6	2	5331
0.19	0.038	0.61	16.0	4	56	S	6	3	4784
0.34	0.050	0.78	05.7	2	08	S	6	4	4888

TABLE 9 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm-1)	NUMBER RIGHT	MEAN CONFIDENCE (in %)	TASK	P.I.	ORDER NO.	SCENE NO.
0.54	0.054	0.62	18.0	3	34	S	6	5	4861
0.29	0.042	0.44	08.6	1	10	S	6	6	4492
0.41	0.041	0.55	17.0	7	32	S	6	7	5386
0.62	0.050	0.60	06.7	6	47	S	6	8	4750
0.12	0.039	0.53	12.0	2	16	S	6	9	5394
0.17	0.037	0.54	17.0	3	38	S	6	10	4914
0.11	0.040	0.51	09.2	1	30	S	7	1	4784
0.17	0.051	0.58	11.0	4	14	S	7	2	4888
0.40	0.085	0.53	12.0	3	50	S	7	3	5331
0.50	0.042	0.55	22.0	3	33	S	7	4	5394
0.38	0.042	0.63	06.7	3	44	S	7	5	4750
0.61	0.055	0.53	07.2	6	44	S	7	6	5386
0.38	0.064	0.52	07.8	3	32	S	7	7	4463
0.41	0.067	0.60	04.8	3	13	S	7	8	4914
0.48	0.023	0.56	07.3	2	60	S	7	9	4492
0.29	0.038	0.60	04.2	1	12	S	7	10	4861
0.44	0.051	0.62	10.4	7	82	S	8	1	4888
0.21	0.037	0.66	08.9	4	66	S	8	2	5386
0.25	0.032	0.60	11.0	3	71	S	8	3	5331
0.41	0.035	0.62	07.3	5	88	S	8	4	4784
0.64	0.055	0.45	07.0	3	56	S	8	5	4914
0.38	0.035	0.53	14.0	5	79	S	8	6	4463
0.39	0.040	0.48	40.0	0	36	S	8	7	4861
0.55	0.046	0.56	04.7	4	67	S	8	8	5394
0.26	0.035	0.64	10.0	6	81	S	8	9	4750
0.12	0.026	0.60	05.2	3	44	S	8	10	4492
0.44	0.072	0.59	10.0	3	30	S	9	1	4888
0.75	0.031	0.36	06.2	3	13	S	9	2	5394
0.52	0.033	0.55	16.0	4	68	S	9	3	4463
0.45	0.062	0.58	03.9	2	39	S	9	4	4861
0.12	0.035	0.53	06.7	0	52	S	9	5	4784
0.21	0.028	0.62	04.4	4	29	S	9	6	5386
0.22	0.034	0.60	06.2	1	38	S	9	7	4750
0.11	0.031	0.59	04.8	0	19	S	9	8	5331
0.26	0.035	0.59	08.4	5	38	S	9	9	4492
0.21	0.045	0.67	07.2	4	30	S	9	10	4912
0.24	0.038	0.58	05.7	2	46	S	10	1	4492
0.46	0.044	0.67	11.0	5	45	S	10	2	5331

TABLE 9 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	TASK	P.I.	ORDER NO.	SCENE NO.
0.52	0.064	0.80	09.5	2	31	S	10	3	4861
0.42	0.049	0.61	12.0	7	62	S	10	4	5386
0.47	0.099	0.66	07.8	3	33	S	10	5	4750
0.32	0.042	0.52	07.3	3	17	S	10	6	4888
0.32	0.053	0.59	07.5	2	40	S	10	7	4784
0.05	0.023	0.59	07.8	3	21	S	10	8	4463
0.17	0.036	0.80	03.0	4	21	S	10	9	4914
0.16	0.033	0.64	08.8	3	28	S	10	10	5394

Appendix V DETERMINATION TEST

This appendix is composed of two tables and two figures. Table 10 lists: (a) the measured values for each of the four variables (defined in Section II), used to describe the photograph, (b) the number of targets correctly identified by the photo interpreter and his mean confidence in the identification, and (c) the photo interpreter, the scene and set up number involved.

The scene and set up number (i.e., the film-spatial filter-contrast combination) were photographically printed on each of the 1000 photographs. In the interpretative test these two numbers were hidden by the cardboard frame and identifications were maintained by adding a PI and order number. Table 11 is a conversion table to find the set up and scene numbers that correspond to a PI and order number.

Histograms of the distribution of interpreter scores are shown in Figure 19 for each original scene and Figure 20 for each interpreter.

TABLE 10

DETERMINATION TEST DATA

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.86	0.062	0.51	18.0	1	49	1	1	21
0.58	0.062	0.34	07.5	2	54	2	1	229
0.71	0.150	0.37	14.0	0	72	3	1	203
0.39	0.150	0.48	17.0	0	42	4	1	47
0.69	0.098	0.42	08.5	0	12	5	1	149
0.52	0.038	0.34	07.5	2	40	6	1	221
0.46	0.062	0.55	09.5	1	31	7	1	60
0.53	0.150	0.46	12.0	2	30	8	1	133
0.69	0.150	0.42	08.5	1	31	9	1	151
0.37	0.038	0.42	08.5	0	52	10	1	136
0.69	0.062	0.42	15.0	3	49	11	1	179
0.23	0.098	0.42	08.5	2	18	12	1	150
0.38	0.038	0.42	08.5	1	35	13	1	137
1.23	0.098	0.50	15.0	4	78	14	1	111
0.37	0.062	0.46	12.0	1	33	15	1	125
0.49	0.150	0.55	09.5	0	30	16	1	69
0.50	0.062	0.37	14.0	0	26	17	1	194
0.44	0.062	0.37	14.0	1	40	18	1	193
0.70	0.098	0.42	15.0	1	19	19	1	183
0.51	0.150	0.52	05.0			20	1	82
0.75	0.062	0.48	17.0			21	1	93
0.44	0.062	0.48	17.0			22	1	38
0.35	0.150	0.48	17.0			23	1	49
0.40	0.150	0.52	05.0			24	1	84
0.12	0.038	0.37	14.0			25	1	190
0.19	0.150	0.48	12.0	2	64	1	2	30
0.81	0.062	0.39	08.8	1	69	2	2	215
0.26	0.062	0.45	07.0	2	79	3	2	145
0.57	0.098	0.39	08.8	0	63	4	2	217
0.52	0.098	0.52	08.7	0	39	5	2	64
0.41	0.038	0.38	09.8	6	95	6	2	187
0.36	0.038	0.45	07.0	2	58	7	2	137
0.39	0.038	0.41	10.0	2	66	8	2	173
0.83	0.098	0.47	11.0	2	39	9	2	112
0.63	0.062	0.39	08.8	2	68	10	2	212
0.36	0.098	0.46	09.5	3	68	11	2	129
0.86	0.038	0.48	12.0	1	43	12	2	16
0.61	0.062	0.47	11.0	5	63	13	2	107
0.42	0.062	0.48	12.0	5	80	14	2	25

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.16	0.038	0.45	07.0	1	36	15	2	139
0.54	0.150	0.52	08.7	2	44	16	2	67
0.57	0.062	0.48	12.0	4	73	17	2	37
0.63	0.098	0.34	06.3	0	47	18	2	234
0.12	0.038	0.39	08.8	1	06	19	2	208
0.58	0.098	0.53	04.7			20	2	78
0.39	0.062	0.45	07.0			21	2	144
0.51	0.150	0.45	07.0			22	2	151
0.11	0.038	0.48	12.0			23	2	33
0.24	0.062	0.42	04.6			24	2	160
0.79	0.098	0.38	09.8			25	2	197
0.38	0.062	0.46	12.0	2	63	1	3	94
0.10	0.150	0.48	12.0	0	42	2	3	50
0.41	0.062	0.34	06.3	2	94	3	3	229
0.19	0.038	0.34	06.3	0	57	4	3	225
0.40	0.062	0.48	12.0	0	56	5	3	10
0.24	0.038	0.48	12.0	4	75	6	3	2
0.26	0.150	0.53	04.7	1	81	7	3	83
1.34	0.098	0.52	08.7	2	59	8	3	61
0.71	0.098	0.52	08.7	2	52	9	3	62
0.69	0.098	0.34	06.3	0	71	10	3	233
0.27	0.150	0.45	07.0	2	52	11	3	154
0.20	0.150	0.52	08.7	1	21	12	3	68
0.23	0.062	0.48	12.0	4	51	13	3	9
0.59	0.098	0.48	12.0	2	90	14	3	12
0.24	0.150	0.46	09.5	1	55	15	3	134
1.05	0.098	0.47	11.0	4	72	16	3	111
0.62	0.098	0.48	12.0	3	76	17	3	13
0.37	0.098	0.41	10.0	1	67	18	3	185
0.26	0.062	0.39	08.8	3	42	19	3	214
0.81	0.098	0.48	12.0			20	3	41
0.16	0.098	0.46	09.5			21	3	127
0.48	0.150	0.52	08.7			22	3	67
0.64	0.062	0.47	11.0			23	3	106
1.06	0.098	0.39	08.8			24	3	216
0.25	0.062	0.52	08.7			25	3	60
0.23	0.038	0.42	14.9	3	71	1	4	173
1.39	0.098	0.48	16.6	3	78	2	4	42
0.80	0.098	0.52	05.0	3	72	3	4	80
1.21	0.098	0.49	16.8	3	75	4	4	98
2.15	0.062	0.37	14.0	2	28	5	4	191
1.08	0.098	0.46	12.3	4	69	6	4	128
0.83	0.098	0.37	14.0	3	67	7	4	198
0.50	0.062	0.55	09.5	4	59	8	4	59

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.85	0.098	0.42	14.9	5	56	9	4	184
0.60	0.098	0.55	09.5	1	36	10	4	64
0.88	0.038	0.52	18.0	5	78	11	4	2
0.32	0.038	0.55	09.5	4	49	12	4	54
0.48	0.098	0.55	09.5	2	42	13	4	65
0.84	0.098	0.39	10.4	3	88	14	4	220
0.90	0.062	0.49	16.8	2	81	15	4	95
2.00	0.098	0.55	09.5	4	84	16	4	61
1.32	0.062	0.42	14.9	7	90	17	4	178
0.80	0.038	0.50	15.0	3	81	18	4	101
1.55	0.062	0.42	14.9	8	63	19	4	176
0.24	0.038	0.34	07.5			20	4	225
1.93	0.098	0.48	16.6			21	4	41
1.18	0.062	0.46	12.3			22	4	122
0.36	0.038	0.42	08.5			23	4	140
1.09	0.062	0.42	08.5			24	4	142
2.17	0.098	0.39	10.4			25	4	216
0.46	0.150	0.38	09.8	4	66	1	5	202
1.01	0.098	0.29	04.4	0	59	2	5	242
0.96	0.098	0.46	12.0	5	81	3	5	99
0.61	0.062	0.52	08.7	1	66	4	5	56
0.39	0.062	0.53	04.7	2	45	5	5	73
0.61	0.038	0.52	08.7	4	99	6	5	52
1.13	0.150	0.42	04.6	3	57	7	5	166
0.42	0.038	0.48	11.6	5	75	8	5	34
0.71	0.038	0.45	07.0	2	42	9	5	136
0.15	0.098	0.39	08.8	1	47	10	5	216
0.93	0.098	0.34	06.3	3	70	11	5	231
0.79	0.098	0.38	09.8	2	75	12	5	198
0.87	0.062	0.46	09.5	0	73	13	5	123
0.75	0.062	0.34	06.3	4	87	14	5	227
0.40	0.150	0.53	04.7	3	88	15	5	84
0.61	0.098	0.48	12.4	1	77	16	5	13
0.70	0.062	0.46	12.0	5	52	17	5	93
1.19	0.098	0.46	12.0	1	48	18	5	97
0.79	0.062	0.53	06.3	3	59	19	5	229
0.52	0.062	0.53	04.7			20	5	74
0.64	0.062	0.34	06.3			21	5	228
0.79	0.062	0.45	07.0			22	5	141
0.44	0.038	0.48	12.4			23	5	1
0.80	0.062	0.46	12.0			24	5	91
0.86	0.098	0.47	11.2			25	5	112

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.17	0.038	0.55	09.5	0	56	1	6	53
0.63	0.098	0.52	05.0	1	42	2	6	76
0.24	0.150	0.55	09.5	0	57	3	6	70
0.34	0.038	0.37	14.0	0	44	4	6	186
0.48	0.098	0.49	17.0	0	11	5	6	100
0.55	0.062	0.37	14.0	4	65	6	6	192
0.35	0.062	0.52	05.0	0	39	7	6	72
0.59	0.098	0.34	07.5	3	74	8	6	232
0.23	0.038	0.37	14.0	1	39	9	6	189
0.43	0.038	0.50	15.0	1	77	10	6	102
0.25	0.038	0.34	07.5	3	51	11	6	222
0.38	0.038	0.46	12.0	1	34	12	6	116
0.56	0.098	0.52	05.0	1	21	13	6	77
0.36	0.150	0.52	05.0	1	72	14	6	83
0.55	0.098	0.42	15.0	0	26	15	6	184
0.26	0.038	0.42	15.0	2	59	16	6	173
0.18	0.038	0.34	07.5	1	28	17	6	223
0.33	0.038	0.37	14.0	3	30	18	6	188
0.25	0.150	0.48	16.6	0	36	19	6	48
0.12	0.038	0.52	18.0			20	6	5
0.43	0.038	0.50	15.0			21	6	109
0.38	0.062	0.42	15.0			22	6	180
0.34	0.062	0.43	04.8			23	6	160
0.40	0.062	0.42	15.0			24	6	178
0.22	0.038	0.46	12.0			25	6	118
0.17	0.038	0.42	08.5	1	44	1	7	139
0.45	0.038	0.49	16.8	1	57	2	7	94
0.62	0.062	0.37	14.0	3	66	3	7	192
0.53	0.062	0.34	07.5	0	11	4	7	228
0.18	0.038	0.49	16.8	0	06	5	7	89
0.62	0.038	0.39	10.4	2	61	6	7	206
0.26	0.038	0.55	09.5	2	51	7	7	53
0.11	0.150	0.52	05.0	1	27	8	7	85
0.13	0.038	0.48	16.6	0	07	9	7	35
0.57	0.098	0.48	16.6	1	70	10	7	44
0.43	0.098	0.52	18.0	4	60	11	7	15
0.18	0.038	0.52	18.0	0	32	12	7	5
1.10	0.098	0.42	08.5	3	48	13	7	146
0.30	0.062	0.37	14.0	1	49	14	7	195
0.33	0.150	0.55	09.5	0	50	15	7	69
0.65	0.098	0.33	04.3	1	28	16	7	242
0.56	0.098	0.52	05.0	1	03	17	7	79
0.65	0.062	0.39	10.4	0	47	18	7	212
0.72	0.062	0.50	15.0	4	58	19	7	107

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in%)	P.I.	SCENE	SET UP NUMBER
0.39	0.098	0.34	07.5			20	7	235
0.20	0.038	0.55	09.5			21	7	54
0.60	0.098	0.42	08.5			22	7	149
0.24	0.038	0.49	16.8			23	7	88
0.52	0.150	0.33	04.3			24	7	248
0.52	0.038	0.50	15.0			25	7	101
0.87	0.038	0.42	14.9	2	63	1	8	171
0.55	0.062	0.50	15.0	3	74	2	8	109
0.55	0.038	0.50	15.0	3	79	3	8	101
0.67	0.150	0.33	04.3	0	51	4	8	247
0.68	0.150	0.52	05.0	0	32	5	8	81
0.51	0.098	0.52	18.0	2	76	6	8	15
0.45	0.150	0.43	04.8	0	38	7	8	168
0.80	0.062	0.52	18.0	3	58	8	8	7
0.48	0.150	0.42	08.5	1	50	9	8	152
1.09	0.150	0.37	14.0	0	76	10	8	201
0.32	0.098	0.50	15.0	2	41	11	8	115
0.90	0.098	0.52	18.0	8	26	12	8	12
0.70	0.062	0.39	10.4	0	24	13	8	213
0.52	0.062	0.48	16.6	5	74	14	8	40
0.64	0.038	0.51	17.6	2	53	15	8	16
0.55	0.062	0.48	16.6	2	60	16	8	39
0.56	0.150	0.46	12.6	2	48	17	8	132
0.84	0.062	0.42	08.5	1	70	18	8	143
0.35	0.038	0.51	17.6	2	53	19	8	18
0.49	0.062	0.37	14.0			20	8	196
0.30	0.038	0.50	15.0			21	8	102
0.38	0.062	0.55	09.5			22	8	59
0.50	0.062	0.49	16.8			23	8	95
0.52	0.098	0.52	05.0			24	8	80
0.40	0.038	0.39	10.4			25	8	207
0.47	0.062	0.53	04.7	2	49	1	9	71
0.23	0.038	0.46	12.0	3	84	2	9	87
0.53	0.150	0.52	08.7	3	85	3	9	66
0.44	0.150	0.34	06.3	3	37	4	9	237
0.57	0.150	0.46	09.5	0	30	5	9	132
0.27	0.150	0.48	11.6	2	77	6	9	50
0.32	0.038	0.45	07.0	2	73	7	9	138
0.43	0.098	0.42	04.6	0	32	8	9	164
0.82	0.098	0.45	07.0	1	56	9	9	146
0.34	0.062	0.42	04.6	3	56	10	9	158
0.37	0.038	0.47	11.2	3	73	11	9	102

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.24	0.062	0.53	04.7	1	27	12	9	74
0.74	0.098	0.46	09.5	2	43	13	9	127
0.78	0.098	0.48	12.4	3	79	14	9	14
0.61	0.062	0.42	04.6	2	76	15	9	157
0.57	0.062	0.52	08.7	3	49	16	9	57
0.35	0.150	0.42	04.6	2	24	17	9	168
0.38	0.150	0.38	09.8	2	55	18	9	204
0.31	0.062	0.48	12.4	2	14	19	9	9
0.30	0.038	0.48	12.0			20	9	19
0.67	0.062	0.45	07.0			21	9	141
0.65	0.062	0.46	09.5			22	9	124
0.22	0.038	0.34	06.3			23	9	223
0.71	0.150	0.48	11.6			24	9	46
0.72	0.062	0.48	11.6			25	9	37
0.54	0.098	0.46	12.0	3	68	1	10	100
0.61	0.038	0.52	08.7	3	91	2	10	51
0.77	0.150	0.38	09.8	2	97	3	10	204
0.51	0.098	0.53	04.7	0	57	4	10	79
0.28	0.038	0.46	12.0	0	34	5	10	90
0.43	0.038	0.47	11.2	4	87	6	10	102
0.47	0.038	0.52	08.7	5	87	7	10	52
1.23	0.038	0.41	10.0	2	72	8	10	171
0.52	0.062	0.48	12.0	4	90	9	10	23
0.26	0.098	0.42	04.6	1	66	10	10	164
0.62	0.098	0.34	06.3	3	81	11	10	234
0.53	0.062	0.48	12.4	4	50	12	10	10
0.28	0.038	0.39	08.8	3	58	13	10	209
0.90	0.150	0.38	09.8	2	83	14	10	202
0.14	0.150	0.54	04.7	4	77	15	10	85
0.34	0.062	0.42	04.6	2	83	16	10	159
0.32	0.098	0.39	08.8	4	76	17	10	220
0.69	0.150	0.29	04.4	3	88	18	10	246
0.23	0.038	0.48	11.6	5	63	19	10	34
0.27	0.038	0.48	11.6			20	10	33
0.79	0.062	0.53	04.7			21	10	72
1.27	0.098	0.34	06.3			22	10	231
0.39	0.062	0.34	06.3			23	10	230
0.24	0.038	0.48	05.9			24	10	2
0.77	0.098	0.34	06.3			25	10	232
0.29	0.062	0.49	16.8	5	72	1	11	92
0.09	0.038	0.50	15.0	0	50	2	11	105
0.21	0.098	0.39	10.4	0	58	3	11	220

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.24	0.062	0.37	14.0	2	30	4	11	192
0.06	0.150	0.42	08.5	1	20	5	11	155
0.21	0.062	0.42	08.5	1	60	6	11	143
0.13	0.098	0.39	10.4	1	61	7	11	219
0.20	0.062	0.39	10.4	1	54	8	11	215
0.18	0.098	0.37	14.0	1	45	9	11	199
0.19	0.098	0.42	08.5	2	52	10	11	147
0.24	0.062	0.46	12.3	5	69	11	11	121
0.11	0.150	0.34	07.5	0	27	12	11	239
0.09	0.062	0.34	07.5	2	39	13	11	230
0.15	0.062	0.49	16.8	2	70	14	11	94
0.23	0.062	0.34	07.5	4	81	15	11	226
0.19	0.098	0.43	04.8	0	27	16	11	163
0.10	0.150	0.48	16.6	0	00	17	11	50
0.41	0.062	0.43	04.8	2	48	18	11	156
0.27	0.098	0.46	12.3	1	36	19	11	128
0.37	0.098	0.33	04.3			20	11	241
0.27	0.098	0.39	10.4			21	11	218
0.10	0.038	0.49	16.8			22	11	88
0.09	0.038	0.42	14.9			23	11	174
0.22	0.098	0.42	08.5			24	11	146
0.20	0.062	0.50	15.0			25	11	109
0.28	0.150	0.46	09.5	2	51	1	12	133
0.25	0.150	0.34	06.3	1	26	2	12	240
0.22	0.150	0.48	11.6	0	50	3	12	50
0.15	0.150	0.46	09.5	3	25	4	12	131
0.48	0.098	0.47	11.2	3	57	5	12	113
0.29	0.098	0.45	07.0	2	43	6	12	147
0.33	0.038	0.46	12.0	2	63	7	12	87
0.30	0.062	0.47	11.2	0	45	8	12	110
0.37	0.062	0.46	09.5	1	25	9	12	124
0.35	0.098	0.47	11.2	0	11	10	12	115
0.22	0.038	0.52	08.7	2	40	11	12	63
0.23	0.038	0.48	12.4	2	21	12	12	4
0.10	0.038	0.47	11.2	0	22	13	12	104
0.28	0.150	0.52	08.7	1	49	14	12	68
0.18	0.098	0.42	04.6	1	15	15	12	165
0.21	0.038	0.48	12.4	1	22	16	12	3
0.12	0.062	0.52	08.7	6	46	17	12	59
0.47	0.062	0.46	09.5	1	38	18	12	122
0.12	0.150	0.48	12.0	1	03	19	12	29
0.25	0.038	0.52	08.7			20	12	52
0.04	0.038	0.46	09.5			21	12	120
0.44	0.038	0.46	09.5			22	12	117
0.15	0.038	0.38	09.8			23	12	188
0.07	0.038	0.46	09.5			24	12	119
0.51	0.098	0.46	09.5			25	12	127

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.27	0.150	0.42	08.5	0	49	1	13	240
0.22	0.062	0.48	16.6	3	38	2	13	40
0.24	0.098	0.39	10.4	2	74	3	13	218
0.33	0.038	0.42	08.5	1	56	4	13	138
0.24	0.098	0.48	16.6	3	35	5	13	44
0.28	0.098	0.55	09.5	4	72	6	13	63
0.24	0.062	0.42	08.5	4	60	7	13	144
0.27	0.150	0.42	08.5	1	45	8	13	155
0.52	0.062	0.37	14.0	3	69	9	13	191
0.15	0.038	0.50	15.0	1	17	10	13	105
0.34	0.098	0.37	14.0	1	64	11	13	198
0.29	0.038	0.46	12.3	1	23	12	13	120
0.34	0.098	0.42	08.5	4	56	13	13	147
0.54	0.098	0.42	14.9	3	77	14	13	182
0.44	0.098	0.49	16.8	5	57	15	13	97
0.08	0.038	0.50	15.0	1	46	16	13	104
0.12	0.038	0.50	15.0	3	61	17	13	103
0.73	0.098	0.46	12.3	6	78	18	13	126
0.33	0.038	0.39	10.4	3	64	19	13	206
0.21	0.038	0.48	16.6			20	13	32
0.22	0.098	0.46	12.3			21	13	130
0.11	0.038	0.51	17.6			22	13	18
0.15	0.038	0.48	16.6			23	13	34
0.62	0.098	0.50	15.0			24	13	112
0.15	0.062	0.43	04.8			25	13	159
0.39	0.062	0.38	09.8	2	55	1	14	194
0.17	0.062	0.48	11.6	2	42	2	14	39
0.33	0.038	0.46	09.5	4	55	3	14	118
0.70	0.098	0.45	07.0	1	60	4	14	148
0.43	0.062	0.45	07.0	1	29	5	14	145
0.45	0.150	0.34	06.3	2	82	6	14	240
0.37	0.038	0.48	11.6	6	81	7	14	32
0.34	0.038	0.48	12.4	1	44	8	14	3
0.53	0.150	0.48	12.0	2	60	9	14	26
0.54	0.098	0.45	07.0	1	54	10	14	150
0.41	0.150	0.42	04.6	2	42	11	14	169
0.33	0.150	0.29	04.4	1	24	12	14	250
0.42	0.150	0.34	06.3	3	40	13	14	238
0.32	0.038	0.48	12.0	4	85	14	14	18
0.32	0.038	0.48	12.0	2	36	15	14	17
0.65	0.038	0.38	09.8	2	69	16	14	187
1.07	0.098	0.41	10.0	5	64	17	14	181
0.74	0.098	0.48	11.6	5	21	18	14	45
0.51	0.098	0.52	08.7	2	49	19	14	64

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (In %)	P.I.	SCENE	SET UP NUMBER
0.94	0.098	0.48	12.4			20	14	11
0.80	0.150	0.29	04.4			21	14	246
0.71	0.098	0.41	10.0			22	14	182
0.51	0.062	0.47	11.2			23	14	109
0.38	0.150	0.38	09.8			24	14	204
0.53	0.150	0.45	07.0			25	14	154
1.69	0.098	0.39	10.4	0	25	1	15	216
0.83	0.098	0.39	10.4	1	33	2	15	218
0.15	0.150	0.33	04.3	0	32	3	15	250
0.94	0.062	0.52	05.0	0	30	4	15	71
0.77	0.150	0.33	04.3	0	44	5	15	248
0.44	0.150	0.33	04.3	0	16	6	15	249
1.03	0.098	0.42	08.5	0	11	7	15	149
0.73	0.038	0.42	08.5	0	09	8	15	136
2.11	0.098	0.33	04.3	2	30	9	15	241
1.56	0.098	0.39	10.4	0	31	10	15	217
0.67	0.098	0.33	04.3	0	14	11	15	245
1.57	0.062	0.42	14.9	0	11	12	15	176
1.23	0.150	0.33	04.3	0	43	13	15	246
1.07	0.098	0.33	04.3	5	70	14	15	244
0.67	0.038	0.49	16.8	0	39	15	15	87
1.15	0.150	0.33	04.3	0	36	16	15	247
1.77	0.098	0.34	07.5	6	74	17	15	231
1.18	0.062	0.34	07.5	0	39	18	15	227
0.60	0.098	0.55	09.5	0	24	19	15	65
1.26	0.098	0.33	04.3			20	15	243
1.84	0.098	0.46	12.3			21	15	126
0.66	0.038	0.34	07.5			22	15	222
0.48	0.062	0.42	08.5			23	15	145
0.23	0.038	0.49	16.8			24	15	90
0.99	0.150	0.42	08.5			25	15	152
0.35	0.150	0.43	04.8	0	24	1	16	168
0.48	0.038	0.42	14.9	3	34	2	16	175
0.47	0.062	0.52	05.0	1	77	3	16	73
0.38	0.038	0.48	16.6	0	43	4	16	32
0.76	0.062	0.42	08.5	1	45	5	16	143
1.09	0.098	0.52	05.0	1	63	6	16	77
0.45	0.150	0.37	14.0	2	49	7	16	205
0.94	0.038	0.39	10.4	1	58	8	16	206
0.57	0.038	0.34	07.5	0	37	9	16	222
0.37	0.098	0.34	07.5	0	18	10	16	235
0.27	0.038	0.52	18.0	1	13	11	16	5

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
1.35	0.098	0.42	08.5	4	39	12	16	146
0.26	0.038	0.55	09.5	1	01	13	16	55
0.28	0.038	0.50	15.0	1	66	14	16	104
0.62	0.062	0.37	14.0	0	39	15	16	194
0.95	0.062	0.46	12.3	2	56	16	16	122
0.22	0.150	0.43	04.8	0	05	17	16	170
0.32	0.038	0.50	15.0	0	42	18	16	103
0.59	0.150	0.43	04.8	0	18	19	16	167
0.86	0.098	0.50	15.0			20	16	129
0.65	0.038	0.55	09.5			21	16	51
0.56	0.038	0.42	14.9			22	16	174
0.24	0.038	0.39	10.4			23	16	210
0.73	0.062	0.43	04.8			24	16	158
0.81	0.062	0.42	14.9			25	16	179
0.45	0.062	0.48	12.4	4	70	1	17	8
0.67	0.098	0.53	04.7	2	61	2	17	80
0.19	0.150	0.46	09.5	4	64	3	17	135
0.55	0.038	0.45	07.0	1	65	4	17	137
0.90	0.098	0.46	09.5	4	41	5	17	127
1.18	0.150	0.45	07.0	4	70	6	17	151
1.43	0.098	0.48	12.4	2	75	7	17	11
0.98	0.098	0.38	09.8	3	63	8	17	198
0.70	0.098	0.46	12.0	3	46	9	17	100
0.80	0.062	0.52	08.7	2	43	10	17	58
1.09	0.098	0.53	04.7	4	38	11	17	77
0.33	0.038	0.39	08.8	1	29	12	17	208
0.75	0.098	0.47	11.2	2	39	13	17	114
0.51	0.062	0.48	12.4	7	89	14	17	9
0.28	0.150	0.42	04.6	1	45	15	17	170
0.43	0.062	0.47	11.2	5	70	16	17	110
0.63	0.062	0.41	10.0	7	68	17	17	179
0.62	0.038	0.41	10.0	3	59	18	17	172
0.44	0.062	0.42	04.6	1	16	19	17	159
0.63	0.038	0.48	12.4			20	17	1
0.42	0.150	0.38	09.8			21	17	205
0.35	0.038	0.38	09.8			22	17	190
0.63	0.038	0.34	06.3			23	17	221
0.91	0.150	0.52	08.7			24	17	66
0.86	0.098	0.48	11.6			25	17	43
0.22	0.098	0.46	12.3	1	58	1	18	130
0.29	0.038	0.37	14.0	0	57	2	18	189
0.26	0.038	0.49	16.8	4	68	3	18	88

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.18	0.098	0.48	16.6	0	62	4	18	44
0.39	0.098	0.49	16.8	3	45	5	18	98
0.69	0.062	0.51	17.6	7	99	6	18	21
0.28	0.098	0.50	15.0	1	43	7	18	115
0.50	0.098	0.49	16.8	0	43	8	18	97
0.93	0.150	0.46	12.3	2	56	9	18	131
0.27	0.150	0.51	17.6	0	46	10	18	29
0.54	0.098	0.42	08.5	4	52	11	18	147
0.08	0.038	0.39	10.4	0	11	12	18	209
0.27	0.038	0.42	14.9	3	66	13	18	175
0.38	0.098	0.46	12.3	6	70	14	18	129
0.20	0.150	0.55	09.5	0	59	15	18	68
0.32	0.062	0.51	17.6	2	67	16	18	25
0.91	0.098	0.55	09.5	3	78	17	18	61
0.38	0.062	0.51	17.6	4	67	18	18	24
0.29	0.038	0.46	12.3	5	56	19	18	117
0.35	0.062	0.49	16.8			20	18	94
0.47	0.150	0.55	09.5			21	18	66
0.12	0.038	0.48	16.6			22	18	33
0.49	0.062	0.48	16.6			23	18	38
0.58	0.062	0.34	07.5			24	18	226
0.35	0.098	0.37	14.0			25	18	199
1.39	0.098	0.42	14.9	4	50	1	19	181
1.20	0.098	0.43	04.8	3	72	2	19	161
0.36	0.150	0.51	17.6	4	73	3	19	28
0.47	0.038	0.34	07.5	1	73	4	19	221
0.18	0.038	0.34	07.5	1	42	5	19	224
0.33	0.038	0.42	08.5	3	40	6	19	137
0.59	0.098	0.55	09.5	3	86	7	19	63
0.97	0.098	0.49	16.8	3	72	8	19	96
0.68	0.150	0.43	04.8	2	61	9	19	166
0.26	0.038	0.51	17.6	5	81	10	19	18
0.33	0.038	0.39	10.4	3	45	11	19	207
0.23	0.038	0.46	12.3	2	55	12	19	119
0.50	0.098	0.33	04.3	2	17	13	19	244
0.73	0.062	0.34	07.5	3	90	14	19	226
0.51	0.062	0.42	08.5	2	93	15	19	142
0.43	0.062	0.43	04.8	2	69	16	19	158
0.29	0.150	0.55	09.5	3	47	17	19	70
0.74	0.038	0.51	17.6	5	89	18	19	16
1.10	0.098	0.37	07.5	4	32	19	19	232
0.68	0.150	0.34	07.5			20	19	237
0.46	0.062	0.49	16.8			21	19	95
0.48	0.150	0.48	16.6			22	19	48
0.94	0.150	0.48	16.6			23	19	46
0.27	0.038	0.37	14.0			24	19	190
0.59	0.150	0.34	07.5			25	19	239

TABLE 10 (Continued)

CONTRAST	GRAIN	$\left(\frac{\text{PASSBAND}}{\text{RESOLUTION}}\right)$	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.35	0.038	0.48	16.6	1	65	1	20	32
0.45	0.150	0.37	14.0	0	67	2	20	205
0.54	0.062	0.42	08.5	4	85	3	20	144
0.96	0.062	0.39	10.4	1	56	4	20	211
0.35	0.038	0.55	09.5	2	50	5	20	52
0.46	0.098	0.42	08.5	1	84	6	20	150
0.37	0.038	0.34	07.5	1	57	7	20	222
0.39	0.038	0.52	18.0	2	62	8	20	4
0.72	0.062	0.52	05.0	0	57	9	20	71
0.82	0.098	0.49	16.8	1	90	10	20	196
0.40	0.038	0.52	18.0	2	62	11	20	3
0.64	0.062	0.46	12.3	2	61	12	20	123
0.64	0.062	0.46	12.3	1	49	13	20	124
0.27	0.038	0.48	16.6	4	84	14	20	35
0.58	0.098	0.50	15.0	0	99	15	20	114
1.16	0.098	0.34	07.5	1	53	16	20	231
0.38	0.038	0.37	14.0	4	62	17	20	189
0.50	0.038	0.52	18.0	2	58	18	20	1
1.21	0.098	0.33	04.3	0	17	19	20	241
0.23	0.038	0.50	15.0			20	20	104
0.35	0.062	0.37	14.0			21	20	195
1.02	0.098	0.52	05.0			22	20	78
0.55	0.062	0.42	14.9			23	20	179
0.19	0.038	0.42	08.5			24	20	138
0.53	0.098	0.37	14.0			25	20	200
1.25	0.062	0.41	10.0	5	66	1	21	176
0.29	0.038	0.38	09.8	1	47	2	21	187
0.59	0.062	0.48	11.6	6	93	3	21	36
0.46	0.062	0.53	04.7	0	55	4	21	72
0.18	0.150	0.48	12.0	0	17	5	21	30
0.28	0.098	0.38	09.8	3	61	6	21	200
0.39	0.038	0.48	12.8	2	43	7	21	5
0.35	0.098	0.48	11.6	4	64	8	21	43
0.22	0.062	0.52	08.7	0	16	9	21	60
0.77	0.062	0.41	10.0	2	58	10	21	177
0.21	0.098	0.38	09.8	6	82	11	21	196
0.76	0.150	0.45	07.0	1	54	12	21	151
0.42	0.150	0.48	12.0	1	28	13	21	28
0.74	0.062	0.46	12.0	5	[illegible]	14	21	91
0.44	0.062	0.48	12.4	4	99	15	21	8
0.65	0.098	0.53	04.7	3	52	16	21	77
0.24	0.150	0.53	04.7	1	34	17	21	82
0.54	0.098	0.53	04.7	3	41	18	21	79
0.47	0.098	0.53	04.7	3	16	19	21	78

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.35	0.038	0.46	09.5			20	21	116
0.22	0.098	0.29	04.4			21	21	243
0.11	0.038	0.41	10.0			22	21	173
0.58	0.062	0.34	06.3			23	21	227
0.34	0.062	0.47	11.2			24	21	108
0.26	0.062	0.48	12.0			25	21	24
0.27	0.098	0.43	04.8	1	47	1	22	164
0.39	0.098	0.43	04.8	1	59	2	22	162
0.74	0.062	0.46	12.3	4	90	3	22	121
0.48	0.062	0.48	16.6	1	50	4	22	37
0.18	0.062	0.43	04.8	0	22	5	22	160
0.26	0.062	0.51	17.6	3	62	6	22	24
1.10	0.098	0.42	14.9	6	71	7	22	181
0.21	0.150	0.51	17.6	0	18	8	22	29
0.24	0.098	0.46	12.3	0	39	9	22	130
0.15	0.150	0.33	04.3	0	39	10	22	249
0.24	0.098	0.37	14.0	1	38	11	22	204
0.11	0.038	0.51	17.6	0	10	12	22	20
0.12	0.038	0.51	17.6	3	34	13	22	19
0.32	0.062	0.55	09.5	3	64	14	22	58
0.14	0.150	0.33	04.3	0	28	15	22	250
0.27	0.038	0.55	09.5	1	43	16	22	51
0.32	0.150	0.51	17.6	6	41	17	22	27
0.43	0.038	0.49	16.8	3	59	18	22	86
0.75	0.150	0.37	14.0	4	28	19	22	201
0.13	0.062	0.52	05.0			20	22	75
0.21	0.150	0.51	17.6			21	22	28
0.34	0.038	0.42	14.9			22	22	172
0.29	0.098	0.52	18.0			23	22	14
0.35	0.098	0.50	15.0			24	22	113
0.38	0.098	0.55	09.5			25	22	64
0.57	0.062	0.34	06.3	2	52	1	23	227
0.34	0.098	0.42	04.6	2	34	2	23	163
0.89	0.062	0.46	12.0	3	86	3	23	91
0.96	0.098	0.52	08.7	1	66	4	23	62
0.50	0.038	0.38	09.8	3	40	5	23	186
0.33	0.062	0.52	08.7	7	70	6	23	60
0.34	0.098	0.45	07.0	3	70	7	23	150
0.32	0.062	0.48	12.0	4	58	8	23	23
0.29	0.062	0.48	12.4	2	64	9	23	10
0.60	0.098	0.41	10.0	5	81	10	23	183
0.38	0.098	0.52	08.7	4	52	11	23	65

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.41	0.062	0.47	11.2	4	48	12	23	108
0.17	0.038	0.48	12.0	2	57	13	23	20
0.43	0.098	0.34	06.3	5	69	14	23	234
0.58	0.150	0.48	12.0	2	84	15	23	27
0.74	0.098	0.38	09.8	1	64	16	23	196
0.12	0.098	0.42	04.6	1	06	17	23	165
0.34	0.038	0.52	08.7	4	35	18	23	51
0.10	0.150	0.48	12.0	2	04	19	23	30
0.19	0.038	0.48	12.0			20	23	17
0.33	0.150	0.42	04.6			21	23	167
0.57	0.062	0.48	11.6			22	23	37
0.29	0.098	0.38	09.8			23	23	200
0.66	0.062	0.48	11.6			24	23	36
0.74	0.062	0.52	08.7			25	23	56
0.91	0.150	0.34	07.5	1	69	1	24	236
0.74	0.098	0.52	05.0	2	60	2	24	78
0.83	0.062	0.42	08.5	1	78	3	24	142
0.50	0.062	0.52	05.0	1	24	4	24	73
0.44	0.038	0.51	17.6	2	40	5	24	17
0.46	0.038	0.51	17.6	5	84	6	24	19
1.11	0.098	0.50	15.0	4	60	7	24	113
1.68	0.098	0.42	14.9	2	70	8	24	181
0.84	0.150	0.37	14.0	2	52	9	24	203
0.93	0.150	0.48	16.6	2	64	10	24	47
0.54	0.150	0.34	07.5	2	52	11	24	239
0.64	0.150	0.37	14.0	3	32	12	24	205
0.74	0.150	0.55	09.5	1	44	13	24	69
0.28	0.038	0.55	09.5	6	74	14	24	55
1.26	0.098	0.52	18.0	3	78	15	24	12
0.69	0.098	0.42	14.9	6	76	16	24	185
0.95	0.062	0.42	14.9	5	31	17	24	157
1.14	0.150	0.52	05.0	1	34	18	24	81
0.95	0.062	0.42	14.9	3	57	19	24	177
1.20	0.098	0.48	16.6			20	24	42
0.98	0.098	0.46	12.3			21	24	129
0.65	0.062	0.51	17.6			22	24	24
1.07	0.062	0.55	09.5			23	24	56
1.29	0.098	0.43	04.8			24	24	161
0.81	0.062	0.48	16.6			25	24	39
0.36	0.062	0.42	14.9	1	54	1	25	180
0.42	0.098	0.55	09.5	0	49	2	25	62
0.63	0.062	0.42	14.9	2	78	3	25	177
0.28	0.038	0.52	18.0	1	28	4	25	16

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.14	0.038	0.42	08.5	1	45	5	25	138
0.29	0.150	0.43	04.8	0	44	6	25	169
0.30	0.150	0.48	16.6	1	60	7	25	48
0.37	0.062	0.52	05.0	1	22	8	25	75
0.55	0.150	0.34	07.5	0	47	9	25	236
0.39	0.062	0.34	07.5	3	56	10	25	229
0.17	0.038	0.34	07.5	1	24	11	25	224
0.29	0.150	0.51	17.6	3	38	12	25	28
0.53	0.098	0.48	16.6	0	48	13	25	42
0.58	0.098	0.37	14.0	5	81	14	25	197
0.21	0.038	0.34	07.5	2	35	15	25	223
0.44	0.062	0.48	16.6	2	70	16	25	40
0.30	0.062	0.51	17.6	2	49	17	25	23
0.47	0.062	0.42	08.5	4	46	18	25	141
0.34	0.150	0.46	12.3	4	39	19	25	133
0.33	0.098	0.50	15.0			20	25	114
0.49	0.062	0.51	17.6			21	25	22
0.31	0.150	0.33	04.3			22	25	248
0.43	0.062	0,50	15.0			23	25	108
0.36	0.062	0.37	14.0			24	25	194
0.39	0.150	0.43	04.8			25	25	167
0.17	0.062	0.38	09.8	1	65	1	26	195
0.35	0.062	0.46	12.0	5	61	2	26	93
0.32	0.062	0.48	11.6	5	68	3	26	38
0.54	0.098	0.34	06.3	3	55	4	26	233
0.35	0.098	0.47	11.2	1	19	5	26	114
0.47	0.098	0.29	04.4	1	33	6	26	244
0.98	0.098	0.46	12.0	3	86	7	26	96
0.28	0.098	0.41	10.0	3	69	8	26	184
0.82	0.098	0.48	11.6	2	47	9	26	42
0.19	0.150	0.29	04.4	0	36	10	26	248
0.62	0.098	0.42	04.6	2	55	11	26	162
0.82	0.098	0.29	04.4	2	31	12	26	242
0.35	0.150	0.38	09.8	1	58	13	26	202
0.41	0.062	0.38	09.8	3	83	14	26	193
0.51	0.062	0.48	12.4	2	74	15	26	7
0.29	0.038	0.48	12.4	5	87	16	26	1
0.10	0.038	0.39	08.8	3	38	17	26	209
0.17	0.150	0.29	04.4	2	39	18	26	249
0.27	0.150	0.45	07.0	4	42	19	26	153
0.79	0.062	0.38	09.8			20	26	191
0.30	0.062	0.47	11.2			21	26	108
0.11	0.098	0.48	11.6			22	26	45
0.08	0.150	0.42	04.6			23	26	170
0.17	0.038	0.38	09.8			24	26	188
0.14	0.038	0.48	11.6			25	26	31

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.12	0.038	0.51	17.6	5	66	1	27	20
1.28	0.098	0.55	09.5	4	89	2	27	61
0.76	0.150	0.48	16.6	4	81	3	27	46
0.15	0.098	0.48	16.6	0	48	4	27	45
1.29	0.098	0.49	16.8	4	59	5	27	96
1.04	0.098	0.43	04.8	2	68	6	27	161
0.46	0.062	0.42	08.5	4	78	7	27	143
1.04	0.062	0.46	12.3	3	64	8	27	121
0.31	0.062	0.34	07.5	3	44	9	27	230
0.68	0.062	0.43	04.8	2	79	10	27	157
0.20	0.150	0.46	12.3	3	50	11	27	135
0.65	0.062	0.51	17.6	4	70	12	27	22
0.59	0.150	0.52	05.0	3	38	13	27	83
0.44	0.150	0.46	12.3	4	74	14	27	133
0.37	0.062	0.42	14.9	3	87	15	27	178
0.27	0.150	0.48	16.6	2	56	16	27	48
0.21	0.038	0.42	14.9	3	68	17	27	175
0.11	0.038	0.39	10.4	1	62	18	27	209
0.20	0.038	0.34	07.5	2	14	19	27	224
0.50	0.062	0.49	16.8			20	27	93
0.67	0.038	0.42	14.9			21	27	171
0.71	0.150	0.33	04.3			22	27	247
1.09	0.098	0.52	18.0			23	27	12
0.09	0.038	0.55	09.5			24	27	55
1.13	0.098	0.52	18.0			25	27	11
0.23	0.150	0.42	04.2	2	50	1	28	169
0.61	0.150	0.34	06.3	2	39	2	28	238
0.51	0.082	0.39	08.8	3	80	3	28	213
0.72	0.062	0.45	07.0	0	66	4	28	142
0.27	0.150	0.48	11.6	2	30	5	28	49
0.20	0.098	0.39	08.8	1	74	6	28	220
0.66	0.062	0.42	04.6	1	62	7	28	157
0.31	0.150	0.53	04.7	1	30	8	28	84
0.74	0.098	0.41	10.0	2	60	9	28	183
0.78	0.038	0.38	09.8	2	34	10	28	187
0.59	0.150	0.48	11.8	3	49	11	28	47
0.98	0.082	0.42	04.6	2	56	12	28	156
0.69	0.062	0.46	12.0	1	57	13	28	92
0.44	0.038	0.46	12.0	8	85	14	28	86
0.86	0.150	0.46	09.5	3	50	15	28	131
0.84	0.062	0.47	11.2	2	56	16	28	106
0.97	0.062	0.38	09.8	3	47	17	28	192
0.61	0.098	0.45	07.0	2	52	18	28	148
0.88	0.098	0.46	12.0	4	84	19	28	97
0.24	0.038	0.48	12.0			20	28	89

TABLE 10 (Continued)

CONTRAST	GRAIN	$\left(\frac{\text{PASSBAND}}{\text{RESOLUTION}}\right)$	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.39	0.038	0.47	11.2			21	28	101
0.26	0.150	0.45	07.0			22	28	153
0.67	0.150	0.29	04.4			23	28	246
0.44	0.098	0.53	04.7			24	28	79
0.61	0.062	0.47	11.2			25	28	107
0.82	0.098	0.55	09.5	1	61	1	29	63
0.45	0.062	0.37	14.0	2	20	2	29	195
0.66	0.098	0.42	14.9	2	60	3	29	183
0.46	0.038	0.42	14.9	1	63	4	29	172
0.83	0.098	0.33	04.3	0	57	5	29	241
0.31	0.062	0.43	04.8	0	22	6	29	160
0.57	0.038	0.49	16.8	1	49	7	29	86
0.31	0.150	0.43	04.8	0	20	8	29	169
0.27	0.150	0.51	17.6	1	15	9	29	29
0.48	0.150	0.52	05.0	0	54	10	29	82
0.31	0.038	0.48	16.6	0	38	11	29	31
0.20	0.150	0.55	09.5	2	10	12	29	70
1.08	0.098	0.43	04.8	1	29	13	29	161
0.77	0.038	0.37	14.0	3	74	14	29	186
0.44	0.098	0.42	14.9	0	71	15	29	185
0.46	0.098	0.39	10.4	3	59	16	29	218
0.14	0.038	0.39	10.4	1	02	17	29	210
0.82	0.062	0.48	16.6	2	59	18	29	36
0.26	0.098	0.37	14.0	1	05	19	29	200
0.61	0.150	0.37	14.0			20	29	203
0.23	0.098	0.37	14.0			21	29	199
0.18	0.098	0.49	16.8			22	29	100
0.40	0.062	0.39	10.4			23	29	213
0.57	0.098	0.48	16.6			24	29	43
0.11	0.038	0.42	08.5			25	29	140
0.37	0.098	0.52	18.0	3	75	1	30	13
0.18	0.038	0.55	09.5	1	25	2	30	53
0.11	0.038	0.46	12.3	1	73	3	30	119
0.19	0.038	0.39	10.4	3	60	4	30	207
0.14	0.038	0.39	10.4	0	30	5	30	208
0.32	0.062	0.39	10.4	8	78	6	30	214
0.53	0.062	0.51	17.6	6	94	7	30	21
0.12	0.038	0.46	12.3	2	69	8	30	118
0.39	0.062	0.39	10.4	4	36	9	30	213
0.17	0.062	0.50	15.0	2	36	10	30	110
0.15	0.038	0.39	10.4	1	45	11	30	210
0.71	0.062	0.48	16.6	6	53	12	30	36
1.03	0.062	0.39	10.4	7	69	13	30	211

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.12	0.038	0.48	16.6	2	60	14	30	33
0.38	0.098	0.48	16.6	4	94	15	30	44
0.19	0.062	0.46	12.3	3	59	16	30	125
0.54	0.062	0.42	14.9	8	85	17	30	177
0.10	0.038	0.49	16.8	4	51	18	30	90
0.55	0.062	0.39	10.4	7	48	19	30	212
0.13	0.150	0.48	16.6			20	30	49
0.18	0.098	0.33	04.4			21	30	244
0.89	0.038	0.39	10.4			22	30	206
0.37	0.098	0.39	10.4			23	30	219
0.42	0.150	0.39	14.0			24	30	201
0.52	0.150	0.39	14.0			25	30	202
0.12	0.098	0.52	05.0	1	12	1	31	62
0.30	0.062	0.39	08.8	1	33	2	31	214
0.06	0.038	0.52	08.7	0	00	3	31	55
0.20	0.038	0.34	06.3	0	21	4	31	223
0.04	0.038	0.46	09.5	0	17	5	31	118
0.18	0.038	0.48	11.4	1	03	6	31	35
0.11	0.098	0.53	04.7	1	31	7	31	80
0.15	0.098	0.39	08.8	0	01	8	31	219
0.48	0.098	0.47	11.2	4	37	9	31	111
0.09	0.098	0.42	04.6	1	16	10	31	162
0.13	0.150	0.42	04.6	0	14	11	31	168
0.23	0.098	0.42	04.6	0	05	12	31	165
0.04	0.038	0.47	11.2	0	01	13	31	105
0.09	0.062	0.46	12.3	2	69	14	31	123
0.08	0.062	0.52	05.0	1	00	15	31	75
0.13	0.150	0.29	04.4	1	10	16	31	243
0.19	0.098	0.46	09.5	2	22	17	31	128
0.10	0.038	0.48	12.0	1	13	18	31	4
0.22	0.098	0.53	04.7	0	13	19	31	76
0.06	0.150	0.46	09.5			20	31	135
0.16	0.062	0.50	15.0			21	31	106
0.09	0.062	0.34	06.3			22	31	230
0.19	0.062	0.50	15.0			23	31	107
0.17	0.098	0.46	12.0			24	31	98
0.20	0.062	0.34	06.3			25	31	226
0.32	0.062	0.52	05.0	1	63	1	32	74
1.49	0.098	0.48	16.6	2	93	2	32	41
0.85	0.150	0.48	16.6	2	76	3	32	47
0.22	0.038	0.48	16.6	0	64	4	32	35
0.68	0.150	0.51	17.6	1	39	5	32	27
0.75	0.038	0.48	16.6	3	72	6	32	31

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
1.41	0.062	0.37	14.0	5	81	7	32	191
0.80	0.098	0.46	12.3	1	42	8	32	128
0.65	0.038	0.34	07.5	2	53	9	32	221
0.19	0.038	0.46	12.3	1	65	10	32	120
0.43	0.098	0.34	07.5	1	40	11	32	235
0.77	0.062	0.49	16.8	4	58	12	32	92
0.41	0.150	0.46	12.3	1	45	13	32	134
0.97	0.038	0.42	08.5	2	83	14	32	136
0.40	0.098	0.33	04.3	0	26	15	32	245
0.81	0.150	0.34	07.5	1	35	16	32	237
1.27	0.150	0.34	07.5	2	27	17	32	236
1.16	0.062	0.39	10.4	2	58	18	32	211
0.82	0.150	0.51	17.6	3	48	19	32	26
0.13	0.038	0.55	09.5			20	32	54
1.16	0.062	0.52	18.0			21	32	6
0.66	0.150	0.34	07.5			22	32	238
0.79	0.062	0.55	09.5			23	32	57
0.14	0.038	0.42	08.5			24	32	140
0.75	0.098	0.33	04.3			25	32	243
0.55	0.062	0.48	12.0	5	68	1	33	25
0.40	0.038	0.52	08.7	4	59	2	33	54
0.52	0.062	0.53	04.7	2	52	3	33	74
1.12	0.150	0.48	12.0	2	60	4	33	26
0.71	0.062	0.52	08.7	1	26	5	33	58
0.54	0.062	0.48	11.6	2	44	6	33	39
1.82	0.098	0.29	04.4	3	41	7	33	242
0.35	0.038	0.47	11.2	3	50	8	33	105
1.27	0.150	0.53	04.7	2	30	9	33	81
0.77	0.062	0.38	09.8	1	46	10	33	193
0.76	0.062	0.53	04.7	2	56	11	33	75
0.43	0.038	0.48	11.6	3	32	12	33	34
0.80	0.062	0.48	12.4	3	60	13	33	10
1.41	0.062	0.39	08.8	5	88	14	33	211
1.35	0.098	0.53	04.7	3	62	15	33	76
0.91	0.098	0.34	06.3	3	37	16	33	235
1.03	0.062	0.48	12.4	3	65	17	33	6
0.64	0.062	0.46	12.0	5	72	18	33	95
0.39	0.038	0.46	12.0	5	61	19	33	90
0.61	0.150	0.45	07.0			20	33	153
0.71	0.062	0.48	12.4			21	33	7
0.47	0.150	0.45	07.0			22	33	155
1.22	0.150	0.52	08.7			23	33	67
1.48	0.150	0.34	06.3			24	33	236
1.54	0.098	0.46	09.5			25	33	126

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.84	0.098	0.41	10.0	3	64	1	34	184
0.40	0.098	0.48	11.6	3	85	2	34	43
0.39	0.150	0.48	11.6	3	72	3	34	49
0.47	0.062	0.48	12.4	2	57	4	34	9
0.88	0.062	0.46	09.5	4	71	5	34	124
1.20	0.098	0.46	12.0	5	99	6	34	99
0.38	0.150	0.53	04.7	1	68	7	34	85
0.67	0.062	0.47	07.0	2	64	8	34	144
0.92	0.098	0.42	04.6	2	43	9	34	164
0.65	0.038	0.46	09.5	3	72	10	34	116
0.44	0.038	0.48	12.0	7	82	11	34	19
0.49	0.038	0.41	10.0	4	23	12	34	175
0.55	0.038	0.34	06.3	5	60	13	34	225
0.65	0.098	0.48	12.4	5	84	14	34	15
0.81	0.062	0.46	09.5	4	70	15	34	122
0.48	0.038	0.47	11.2	4	67	16	34	103
0.92	0.150	0.52	08.7	5	83	17	34	66
0.85	0.062	0.48	12.4	3	74	18	34	7
1.20	0.150	0.46	09.5	4	46	19	34	131
0.71	0.062	0.41	10.0			20	34	180
0.48	0.038	0.46	09.5			21	34	117
0.60	0.150	0.45	07.0			22	34	154
1.21	0.098	0.47	11.2			23	34	113
0.89	0.098	0.48	12.4			24	34	14
1.15	0.098	0.46	12.0			25	34	98
0.64	0.150	0.37	14.0	2	65	1	35	201
0.44	0.098	0.39	10.4	2	43	2	35	219
0.44	0.062	0.39	10.4	3	74	3	35	215
0.81	0.062	0.42	14.9	0	52	4	35	176
0.53	0.062	0.43	04.8	0	63	5	35	156
0.38	0.150	0.46	12.3	2	50	6	35	135
1.13	0.098	0.42	14.9	4	59	7	35	182
0.73	0.098	0.52	18.0	1	48	8	35	15
0.44	0.150	0.55	09.5	0	64	9	35	70
0.38	0.062	0.52	18.0	1	82	10	35	8
0.44	0.150	0.52	05.0	4	33	11	35	83
0.36	0.062	0.43	04.8	1	47	12	35	158
0.73	0.038	0.37	14.0	6	67	13	35	186
0.48	0.062	0.39	10.4	6	78	14	35	214
0.32	0.150	0.33	04.3	0	09	15	35	249
0.26	0.038	0.46	12.3	3	56	16	35	119
0.71	0.098	0.46	12.3	3	54	17	35	130
0.37	0.038	0.49	16.8	2	58	18	35	88
0.42	0.038	0.49	16.8	2	42	19	35	86
0.51	0.150	0.34	07.5			20	35	239

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.47	0.062	0.46	12.3			21	35	125
0.38	0.062	0.50	15.0			22	35	110
0.36	0.098	0.50	15.0			23	35	115
0.34	0.098	0.42	14.9			24	35	185
0.67	0.062	0.49	16.8			25	35	91
0.31	0.150	0.46	12.3	2	78	1	36	132
0.19	0.062	0.43	04.8	0	41	2	36	159
0.22	0.038	0.42	14.9	2	98	3	36	174
0.27	0.038	0.37	14.0	1	78	4	36	188
0.20	0.062	0.48	16.6	2	47	5	36	38
0.84	0.062	0.52	05.0	4	99	6	36	71
0.29	0.150	0.55	09.5	1	87	7	36	68
0.23	0.150	0.52	05.0	2	84	8	36	82
0.32	0.098	0.42	08.5	1	73	9	36	149
0.91	0.098	0.49	16.8	4	94	10	36	96
0.17	0.038	0.46	12.3	7	71	11	36	117
0.24	0.038	0.49	16.8	2	51	12	36	89
0.19	0.038	0.52	18.0	3	95	13	36	3
0.08	0.038	0.34	07.5	3	86	14	36	225
0.75	0.098	0.52	18.0	5	99	15	36	11
0.56	0.062	0.51	17.6	4	86	16	36	22
0.15	0.150	0.34	07.5	2	80	17	36	240
0.58	0.150	0.34	07.5	4	83	18	36	237
0.72	0.062	0.55	09.5	4	74	19	36	56
0.60	0.098	0.34	07.5			20	36	233
0.09	0.150	0.42	08.5			21	36	154
0.16	0.038	0.37	14.0			22	36	189
0.10	0.038	0.34	07.5			23	36	224
0.89	0.062	0.50	15.0			24	36	106
0.56	0.062	0.55	09.5			25	36	57
0.73	0.098	0.47	11.2	2	78	1	37	112
0.25	0.150	0.45	07.0	1	59	2	37	152
0.46	0.150	0.52	08.7	3	91	3	37	67
0.14	0.062	0.41	10.0	2	45	4	37	180
0.23	0.038	0.39	08.8	2	48	5	37	207
0.32	0.062	0.52	08.7	2	70	6	37	59
0.29	0.062	0.48	12.0	2	88	7	37	23
0.37	0.062	0.52	08.7	2	33	8	37	58
0.77	0.098	0.39	08.8	3	76	9	37	217
0.62	0.062	0.48	12.4	2	76	10	37	6
0.27	0.150	0.52	08.7	1	41	11	37	69
0.97	0.062	0.45	07.0	4	26	12	37	141

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.37	0.098	0.46	12.0	5	60	13	37	99
0.49	0.062	0.48	12.0	7	91	14	37	22
0.35	0.150	0.38	09.8	2	82	15	37	203
0.40	0.150	0.34	06.3	2	45	16	37	238
0.09	0.038	0.48	12.0	3	31	17	37	20
0.40	0.038	0.46	09.5	3	64	18	37	116
0.16	0.038	0.46	12.0	5	36	19	37	89
0.40	0.150	0.46	09.5			20	37	132
0.58	0.062	0.39	08.8			21	37	212
0.65	0.098	0.34	06.3			22	37	232
0.20	0.038	0.41	10.0			23	37	172
0.17	0.150	0.29	04.4			24	37	250
0.11	0.038	0.46	09.5			25	37	120
0.51	0.062	0.55	09.5	3	53	1	38	57
0.46	0.062	0.51	18.0	2	61	2	38	21
0.45	0.062	0.46	12.0	2	85	3	38	123
0.35	0.062	0.51	18.0	3	50	4	38	25
0.63	0.098	0.49	16.8	2	50	5	38	99
0.44	0.150	0.42	08.5	2	63	6	38	145
0.52	0.062	0.37	14.0	2	48	7	38	193
0.55	0.062	0.46	12.0	3	61	8	38	125
0.57	0.062	0.52	18.0	2	70	9	38	6
0.63	0.098	0.34	07.5	0	38	10	38	234
0.34	0.038	0.50	15.0	5	68	11	38	103
0.80	0.098	0.42	08.5	0	30	12	38	148
0.86	0.098	0.37	14.0	3	42	13	38	197
0.49	0.098	0.55	09.5	0	75	14	38	65
0.23	0.038	0.39	10.0	2	58	15	38	210
0.88	0.098	0.48	16.6	1	51	16	38	41
0.33	0.150	0.42	08.5	1	30	17	38	155
0.58	0.150	0.43	04.8	2	19	18	38	166
0.43	0.150	0.46	12.3	1	23	19	38	134
0.62	0.098	0.43	04.8			20	38	163
0.42	0.098	0.33	04.3			21	38	245
0.21	0.038	0.42	08.5			22	38	139
0.57	0.150	0.52	05.0			23	38	81
0.72	0.098	0.52	18.0			24	38	13
0.35	0.038	0.55	09.5			25	38	53
0.22	0.098	0.48	16.6	0	42	1	39	45
0.40	0.062	0.34	07.5	0	45	2	39	228
1.09	0.098	0.42	08.5	1	72	3	39	111
0.17	0.038	0.42	08.5	0	48	4	39	140
0.18	0.038	0.37	14.0	0	42	5	39	190

TABLE 10 (Continued)

CONTRAST	GRAIN	(PASSBAND / RESOLUTION)	RESOLUTION (mm^{-1})	NUMBER RIGHT	MEAN CONFIDENCE (in %)	P.I.	SCENE	SET UP NUMBER
0.22	0.150	0.52	05.0	1	27	6	39	85
0.47	0.098	0.33	04.3	2	44	7	39	245
0.66	0.150	0.51	17.6	0	63	8	39	26
0.13	0.038	0.51	17.6	2	61	9	39	17
0.29	0.150	0.33	04.3	0	43	10	39	247
0.10	0.038	0.39	10.4	1	33	11	39	208
0.15	0.150	0.46	12.3	2	35	12	39	134
0.27	0.038	0.48	16.6	3	59	13	39	31
0.18	0.038	0.52	18.0	4	71	14	39	2
0.91	0.098	0.42	08.5	2	95	15	39	126
0.55	0.098	0.43	04.8	1	33	16	39	162
0.24	0.150	0.43	04.8	1	12	17	39	167
0.31	0.150	0.42	08.5	1	28	18	39	152
0.60	0.098	0.42	14.9	2	44	19	39	182
0.36	0.150	0.51	17.6			20	39	27
0.22	0.098	0.42	08.5			21	39	148
0.72	0.098	0.39	14.0			22	39	197
0.19	0.062	0.39	10.4			23	39	215
0.31	0.062	0.52	18.0			24	39	8
0.84	0.150	0.48	16.6			25	39	46
0.62	0.150	0.42	04.6	0	54	1	40	166
0.48	0.098	0.38	09.8	3	45	2	40	199
0.10	0.038	0.45	07.0	1	30	3	40	139
0.45	0.062	0.42	04.6	0	53	4	40	156
0.88	0.062	0.46	09.5	3	50	5	40	121
0.20	0.098	0.42	04.6	1	27	6	40	165
0.19	0.062	0.48	11.6	2	60	7	40	40
0.32	0.150	0.45	07.0	1	43	8	40	153
0.30	0.098	0.42	04.6	1	37	9	40	163
0.26	0.150	0.53	04.7	0	14	10	40	84
0.34	0.062	0.41	10.0	4	64	11	40	178
0.07	0.150	0.42	04.6	0	02	12	40	170
0.23	0.098	0.48	12.4	2	30	13	40	14
0.59	0.038	0.41	10.0	2	94	14	40	171
0.19	0.038	0.41	10.0	2	48	15	40	174
0.79	0.098	0.53	04.7	4	67	16	40	76
0.32	0.038	0.46	12.0	5	62	17	40	87
0.52	0.062	0.53	04.7	2	54	18	40	73
0.59	0.062	0.53	04.7	0	34	19	40	72
0.09	0.038	0.48	12.0			20	40	4
0.11	0.150	0.48	12.0			21	40	30
0.61	0.098	0.34	06.3			22	40	233
0.40	0.062	0.34	06.3			23	40	228
0.30	0.062	0.46	12.0			24	40	92
0.79	0.098	0.39	08.8			25	40	217

TABLE II

ASSIGNMENT OF MODIFIED SCENES TO PHOTOINTERPRETERS

	P.I. NO. 1			P.I. NO. 2			P.I. NO. 3	
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	19	181	1	9	87	1	16	73
2	34	184	2	14	39	2	22	121
3	10	100	3	22	162	3	3	229
4	37	112	4	5	242	4	9	66
5	35	201	5	20	205	5	13	218
6	27	20	6	1	229	6	36	174
7	2	30	7	6	76	7	21	36
8	11	92	8	15	218	8	11	220
9	16	168	9	11	105	9	37	67
10	20	32	10	7	94	10	38	123
11	4	173	11	8	109	11	10	204
12	39	45	12	21	187	12	4	80
13	3	94	13	2	215	13	17	135
14	28	169	14	19	161	14	20	144
15	36	132	15	12	240	15	18	88
16	24	236	16	13	40	16	23	91
17	18	130	17	16	175	17	26	38
18	5	202	18	30	53	18	19	28
19	21	176	19	3	50	19	5	99
20	6	53	20	29	195	20	14	118
21	40	166	21	23	163	21	24	142
22	31	62	22	39	228	22	6	70
23	7	139	23	17	80	23	27	46
24	17	8	24	31	214	24	30	119
25	13	240	25	24	78	25	7	192
26	12	133	26	18	189	26	15	250
27	22	164	27	26	93	27	8	101
28	14	194	28	10	51	28	1	203
29	38	57	29	25	62	29	25	177
30	1	21	30	27	61	30	28	213
31	8	171	31	28	238	31	12	50
32	9	71	32	40	199	32	29	183
33	25	180	33	32	41	33	31	55
34	15	216	34	36	159	34	32	47
35	23	227	35	33	54	35	33	74
36	26	195	36	37	152	36	39	111
37	29	63	37	34	43	37	34	49
38	30	13	38	35	219	38	40	139
39	32	74	39	38	21	39	35	215
40	33	25	40	4	42	40	2	145

TABLE II (Continued)

P.I. NO. 4			P.I. NO. 5			P.I. NO. 6		
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	26	233	1	13	44	1	11	143
2	13	138	2	23	186	2	9	50
3	30	207	3	6	100	3	17	151
4	27	45	4	4	191	4	16	77
5	19	221	5	7	89	5	35	135
6	14	148	6	26	114	6	32	31
7	31	223	7	5	73	7	37	59
8	8	247	8	19	224	8	13	63
9	32	35	9	8	81	9	29	160
10	35	176	10	9	132	10	36	71
11	28	142	11	25	138	11	12	147
12	40	156	12	32	27	12	5	52
13	20	211	13	10	90	13	33	39
14	33	26	14	11	155	14	26	244
15	34	9	15	14	145	15	14	240
16	16	32	16	28	49	16	15	249
17	15	71	17	33	58	17	27	161
18	21	72	18	15	248	18	6	192
19	2	217	19	27	96	19	8	15
20	29	172	20	29	241	20	18	21
21	17	137	21	38	99	21	19	137
22	1	47	22	16	143	22	38	145
23	36	188	23	30	208	23	39	85
24	37	180	24	31	118	24	20	150
25	38	25	25	17	127	25	40	165
26	39	140	26	12	113	26	28	220
27	3	225	27	18	98	27	34	99
28	4	98	28	34	124	28	30	214
29	22	37	29	20	52	29	7	206
30	18	44	30	21	30	30	1	221
31	5	56	31	22	160	31	22	24
32	23	62	32	24	17	32	23	60
33	24	73	33	35	156	33	10	102
34	6	186	34	39	190	34	2	187
35	7	228	35	36	38	35	21	200
36	25	16	36	40	121	36	24	19
37	9	237	37	37	207	37	25	169
38	10	79	38	1	149	38	3	2
39	11	192	39	2	64	39	31	35
40	12	131	40	3	10	40	4	128

TABLE II (Continued)

P.I. NO. 7			P.I. NO. 8			P.I. NO. 9		
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	31	80	1	19	96	1	36	149
2	18	115	2	13	155	2	37	217
3	5	166	3	27	121	3	13	191
4	29	86	4	18	97	4	25	236
5	23	150	5	11	215	5	27	230
6	24	113	6	7	85	6	40	163
7	25	48	7	28	84	7	15	241
8	34	85	8	5	34	8	16	222
9	15	149	9	6	232	9	8	152
10	14	32	10	20	4	10	10	23
11	10	52	11	8	7	11	6	189
12	1	60	12	31	219	12	39	17
13	30	21	13	29	169	13	3	62
14	32	191	14	15	136	14	32	221
15	35	182	15	21	43	15	22	130
16	4	198	16	14	3	16	38	6
17	21	5	17	23	23	17	23	10
18	16	205	18	16	206	18	9	146
19	20	222	19	38	125	19	35	70
20	8	168	20	30	118	20	14	26
21	22	181	21	32	128	21	24	203
22	6	72	22	12	110	22	19	166
23	40	40	23	33	105	23	28	183
24	33	242	24	40	153	24	17	100
25	36	68	25	9	164	25	18	131
26	37	23	26	35	15	26	29	29
27	2	137	27	37	58	27	1	151
28	3	83	28	22	29	28	21	60
29	17	11	29	10	171	29	2	112
30	12	87	30	25	75	30	20	71
31	26	96	31	24	181	31	26	42
32	11	219	32	34	144	32	5	136
33	19	63	33	17	198	33	7	35
34	7	53	34	26	184	34	30	213
35	13	144	35	36	82	35	31	111
36	9	138	36	39	26	36	4	184
37	27	143	37	1	133	37	11	199
38	28	157	38	2	173	38	12	124
39	38	193	39	3	61	38	33	81
40	39	245	40	4	59	40	34	164

TABLE II (Continued)

P.I. NO. 10			P.I. NO. 11			P.I. NO. 12		
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	32	120	1	40	178	1	2	16
2	33	193	2	10	234	2	9	74
3	6	102	3	7	15	3	36	89
4	29	82	4	14	169	4	33	34
5	37	6	5	38	103	5	15	176
6	7	44	6	13	198	6	8	12
7	26	248	7	20	3	7	34	175
8	35	8	8	21	196	8	18	209
9	24	47	9	37	69	9	40	170
10	20	196	10	32	235	10	22	20
11	39	247	11	33	75	11	17	208
12	1	136	12	5	231	12	37	141
13	14	150	13	2	129	13	1	150
14	9	158	14	8	115	14	3	68
15	27	157	15	34	19	15	4	54
16	34	116	16	9	102	16	11	239
17	18	29	17	31	168	17	35	158
18	8	201	18	22	204	18	23	108
19	36	96	19	11	121	19	5	198
20	12	115	20	15	245	20	19	119
21	17	58	21	39	208	21	6	116
22	11	147	22	12	63	22	38	148
23	5	216	23	16	5	23	39	134
24	4	64	24	17	77	24	27	22
25	19	18	25	18	147	25	7	5
26	30	110	26	35	83	26	16	146
27	38	234	27	19	207	27	20	123
28	21	177	28	23	65	28	21	151
29	28	187	29	24	239	29	24	205
30	10	164	30	30	210	30	26	242
31	40	84	31	1	179	31	25	28
32	13	105	32	25	224	32	10	10
33	22	249	33	26	162	33	12	4
34	15	217	34	36	117	34	13	120
35	16	235	35	27	135	35	28	156
36	31	162	36	28	47	36	14	250
37	2	212	37	29	31	37	29	70
38	3	233	38	3	154	38	30	36
39	23	183	39	4	2	39	31	165
40	25	229	40	6	222	40	32	92

TABLE II (Continued)

P.I. NO. 13			P.I. NO. 14			P.I. NO. 15		
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	27	83	1	25	197	1	7	69
2	24	69	2	21	91	2	11	226
3	30	211	3	37	22	3	15	87
4	38	197	4	11	94	4	37	203
5	10	209	5	22	58	5	34	122
6	2	107	6	33	211	6	28	131
7	35	186	7	15	244	7	40	174
8	25	42	8	2	25	8	35	249
9	20	124	9	40	171	9	6	184
10	18	175	10	14	18	10	16	194
11	7	146	11	20	35	11	32	245
12	11	230	12	23	234	12	12	165
13	9	127	13	24	55	13	18	68
14	26	202	14	1	111	14	17	170
15	34	225	15	30	33	15	29	185
16	3	9	16	38	65	16	3	134
17	4	65	17	19	226	17	4	95
18	22	19	18	31	123	18	8	16
19	19	244	19	36	225	19	30	44
20	15	246	20	32	136	20	13	97
21	28	92	21	29	186	21	19	142
22	8	213	22	18	129	22	38	210
23	40	14	23	16	104	23	33	76
24	31	105	24	17	9	24	20	114
25	16	55	25	7	195	25	31	75
26	13	147	26	39	2	26	26	7
27	17	114	27	26	193	27	21	8
28	21	28	28	3	12	28	14	17
29	29	161	29	4	220	29	5	84
30	12	104	30	5	227	30	27	178
31	32	134	31	6	83	31	10	85
32	23	20	32	27	133	32	23	27
33	33	10	33	8	40	33	22	250
34	36	3	34	34	15	34	24	12
35	37	99	35	9	14	35	36	11
36	39	31	36	10	202	36	39	126
37	1	137	37	12	68	37	1	125
38	5	123	38	35	214	38	25	223
39	6	77	39	28	86	39	2	139
40	14	238	40	13	182	40	9	157

TABLE II (Continued)

	P.I. NO. 16			P.I. NO. 17			P.I. NO. 18	
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	27	48	1	9	168	1	3	185
2	18	25	2	29	210	2	17	172
3	15	247	3	10	220	3	15	227
4	19	158	4	30	177	4	18	24
5	24	185	5	37	20	5	40	73
6	4	61	6	25	23	6	16	103
7	40	76	7	21	82	7	4	101
8	20	231	8	6	223	8	20	1
9	34	103	9	32	236	9	26	249
10	37	238	10	28	192	10	5	97
11	29	218	11	24	157	11	32	211
12	9	57	12	19	70	12	35	88
13	16	122	13	2	37	13	6	188
14	30	125	14	33	6	14	37	116
15	35	119	15	3	13	15	19	16
16	28	106	16	5	93	16	21	79
17	31	243	17	23	165	17	1	193
18	1	69	18	7	79	18	22	86
19	32	237	19	11	50	19	31	4
20	33	235	20	38	155	20	23	51
21	25	40	21	26	209	21	24	81
22	26	1	22	12	59	22	33	95
23	36	22	23	1	194	23	7	212
24	8	39	24	34	66	24	2	234
25	38	41	25	27	175	25	29	36
26	10	159	26	39	167	26	25	141
27	39	162	27	13	103	27	11	156
28	2	67	28	16	170	28	27	209
29	3	111	29	31	128	29	8	143
30	5	13	30	14	181	30	9	204
31	6	173	31	15	231	31	13	126
32	7	242	32	17	179	32	34	7
33	11	163	33	40	87	33	38	166
34	12	3	34	18	61	34	36	237
35	17	110	35	20	189	35	12	122
36	21	77	36	22	27	36	28	148
37	22	51	37	35	130	37	10	246
38	13	104	38	36	240	38	39	152
39	14	187	39	4	178	39	14	45
40	23	196	40	8	132	40	30	90

TABLE II (Continued)

P.I. NO. 19			P.I. NO. 20			P.I. NO. 21		
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	25	133	1	23	17	1	23	167
2	39	182	2	32	54	2	28	101
3	16	167	3	40	4	3	15	126
4	34	131	4	13	32	4	1	93
5	40	72	5	17	1	5	3	127
6	17	159	6	26	191	6	24	129
7	18	117	7	35	239	7	40	30
8	1	183	8	10	33	8	36	154
9	19	232	9	18	94	9	30	244
10	23	30	10	24	42	10	2	144
11	2	208	11	33	153	11	26	108
12	35	86	12	30	49	12	17	205
13	3	214	13	25	114	13	29	199
14	27	224	14	11	241	14	4	41
15	4	176	15	14	11	15	32	6
16	5	229	16	15	243	16	34	117
17	38	134	17	37	132	17	22	28
18	6	48	18	16	129	18	5	228
19	7	107	19	12	52	19	6	109
20	11	128	20	34	180	20	7	54
21	12	29	21	19	237	21	12	120
22	22	201	22	21	118	22	18	66
23	30	212	23	36	233	23	35	125
24	8	18	24	31	135	24	27	171
25	9	9	25	2	78	25	9	141
26	10	34	26	1	82	26	16	51
27	20	241	27	39	27	27	38	245
28	24	177	28	38	163	28	8	102
29	32	28	29	9	19	29	10	72
30	13	206	30	20	104	30	25	22
31	28	153	31	27	93	31	31	106
32	37	89	32	3	41	32	33	7
33	28	97	33	22	75	33	19	95
34	29	200	34	28	89	34	11	218
35	14	64	35	4	225	35	20	195
36	31	76	36	29	203	36	21	243
37	15	65	37	5	74	37	37	212
38	21	78	38	6	5	38	13	130
39	33	90	39	7	235	39	39	148
40	36	56	40	8	196	40	14	246

TABLE II (Continued)

P.I. NO. 22			P.I. NO. 23			P.I. NO. 24		
ORDER	SCENE	SETUP	ORDER	SCENE	SETUP	ORDER	SCENE	SETUP
1	36	189	1	1	49	1	23	36
2	14	182	2	5	1	2	34	14
3	20	78	3	39	215	3	16	158
4	27	247	4	8	95	4	7	248
5	25	248	5	35	115	5	35	185
6	32	238	6	34	113	6	36	106
7	29	100	7	14	109	7	25	194
8	13	18	8	30	219	8	13	112
9	26	45	9	36	224	9	32	140
10	1	38	10	37	172	10	6	178
11	6	180	11	13	34	11	37	250
12	3	67	12	20	179	12	8	80
13	2	151	13	6	160	13	31	98
14	28	153	14	7	88	14	4	142
15	19	48	15	29	213	15	14	204
16	9	124	16	11	174	16	5	91
17	17	190	17	23	200	17	22	113
18	21	173	18	38	81	18	9	46
19	37	232	19	9	223	19	17	66
20	30	206	20	22	14	20	38	13
21	38	139	21	18	38	21	19	190
22	10	231	22	40	228	22	24	161
23	33	155	23	16	210	23	26	188
24	7	149	24	2	33	24	3	216
25	31	230	25	10	230	25	28	79
26	11	88	26	3	106	26	15	90
27	34	154	27	15	145	27	18	226
28	23	37	28	4	140	28	40	92
29	8	59	29	12	188	29	27	55
30	12	117	30	21	227	30	2	160
31	39	197	31	17	221	31	10	2
32	16	174	32	19	46	32	29	43
33	18	33	33	24	56	33	39	8
34	40	233	34	28	246	34	20	138
35	22	172	35	25	108	35	30	201
36	15	222	36	26	170	36	1	84
37	24	24	37	27	12	37	11	146
38	4	122	38	31	107	38	12	119
39	5	141	39	32	57	39	21	108
40	35	110	40	33	67	40	33	236

TABLE II (Continued)

P.I. NO. 25

ORDER	SCENE	SETUP
1	36	57
2	37	120
3	23	56
4	24	39
5	1	190
6	10	232
7	33	126
8	30	202
9	38	53
10	2	197
11	17	43
12	8	207
13	26	31
14	25	167
15	39	46
16	34	98
17	27	11
18	19	239
19	7	101
20	28	107
21	21	24
22	4	216
23	31	226
24	40	217
25	3	60
26	11	109
27	35	91
28	32	243
29	5	112
30	6	118
31	9	37
32	12	127
33	18	199
34	22	64
35	13	159
36	14	154
37	15	152
38	16	179
39	29	140
40	20	200

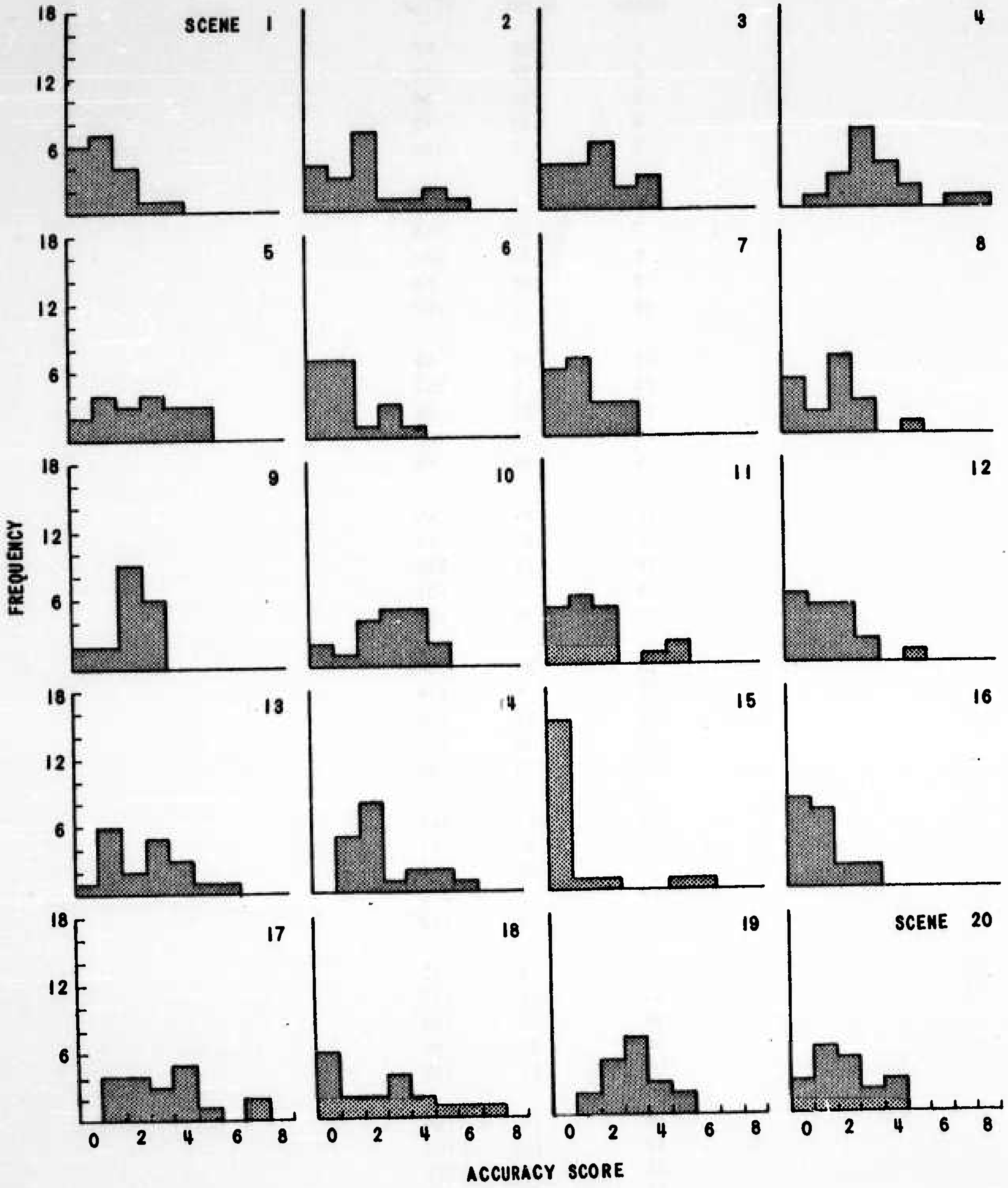


Fig. 19 ACCURACY SCORE DISTRIBUTION FOR EACH ORIGINAL SCENE

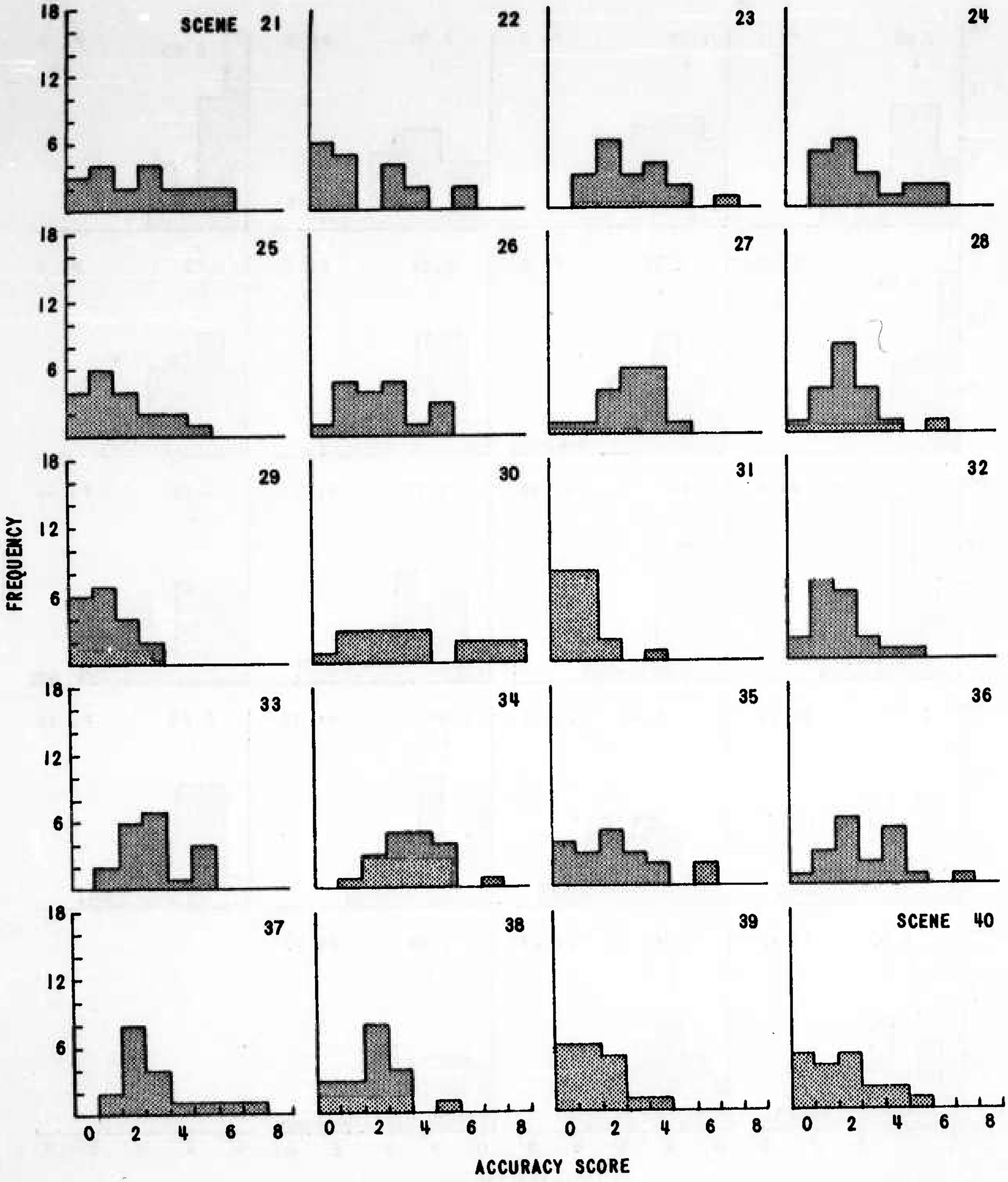


Fig. 19 (CONTINUED) ACCURACY SCORE DISTRIBUTION FOR EACH ORIGINAL SCENE

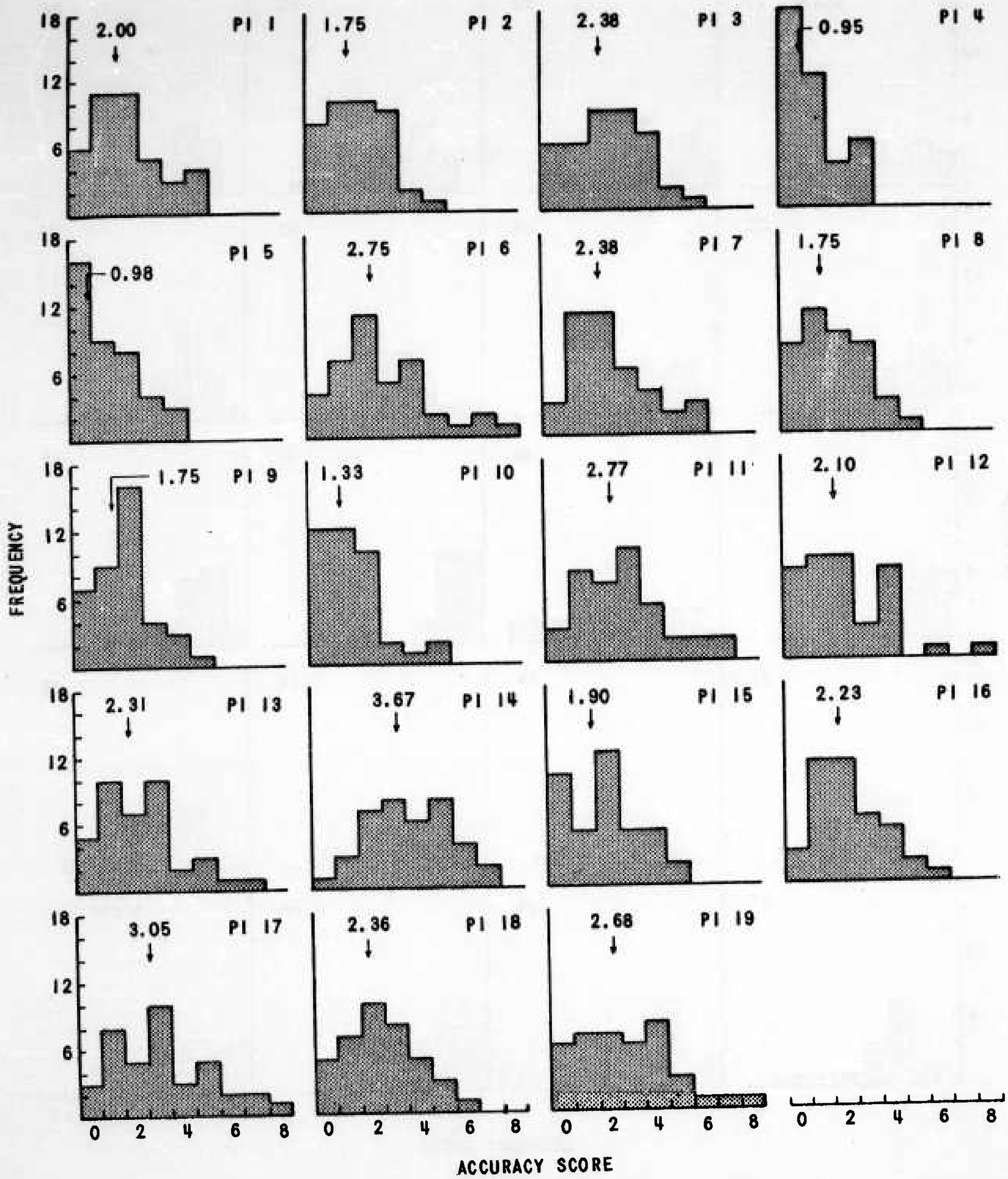


Fig. 20 ACCURACY SCORE DISTRIBUTION FOR EACH PI SUBJECT